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SOME DISEASES OF CEREALS CAUSED BY SCLEROSPORA GRAMINICOLA.

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PLATE I.

Ears of Pennisetum typhoideum affected by Sclerospora graminicola.

SOME DISEASES OF CEREALS CAUSED BY SCLEROSPORA GRAMINICOLA.

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A CURIOUS disease of Pennisetum typhoideum (*bajra*) occurs sporadically in most provinces of India where this cereal is grown. It is not usually of sufficient intensity to attract much notice; but at times, particularly in low-lying ill-drained land, it develops into epidemics of varying severity. Its chief interest is, however, at present pathological, for it is one of a small number of diseases, caused by parasites, which produce deep alterations in the reproductive parts of plants, resulting in great modification in the floral organs and entire or partial sterility.

The general appearance of diseased ears is represented in plate I. The spicate inflorescence, from which this species obtains its name of the bulrush millet, is transformed wholly or in part into a loose green head, composed for the most part of small twisted leaves. Every stage can be found between ears in which the greater part ripens its grain normally, only a small propoition showing the characteristic deformity, and ears entirely affected and absolutely sterile.

To understand the changes in the inflorescence to which this appearance is due, it is necessary, in the first place, to have a clear idea of the structure of the normal inflorescence. The *bajra* ear is composed of crowded spikelets arranged around a woolly, unbranched axis, the whole ear being up to a foot long, by one, or one

and a half inches broad. The spikelets (plate II, fig. 1) are pedicellate, the pedicel being jointed below a bristly involucre, which encloses usually one, but sometimes two to six (Prain) or eight (Gammie) spikelets. I have rarely found more than two on the diseased ears which are those that I have chiefly dissected. The rachilla of the spikelet is simple, and not prolonged beyond the upper floret. In the other Penniseti, when ripe, the pedicel breaks below the involucre which is carried on the fallen spikelet. In cultivated *bajra* the involucre is, however, usually persistent. The involucre consists of simple, or more usually, feathery bristles, unequal in length, but normally projecting slightly beyond the glumes. The lower two glumes on each spikelet are sterile; the lowest being always minute and sometimes altogether absent. Its veins are not visible. The second is often also minute, but may be nearly equal to the fertile glumes, and is three, five, or seven veined. Both these are obtuse, or the first is occasionally, and the second more often truncate or retuse and ciliated near the tip on the margins. The third and fourth glumes are usually fertile; the third enclosing a palea within which are three stamens. The paleæ and stamens are sometimes absent. The lower floret is, therefore, male or sterile. The fourth glume is paleate, and encloses three stamens and an ovary, or only the latter. There are two minute lodicules. The fertile glumes III and IV are boat-shaped, with a more or less shortly mucronate apex, ciliate at the margins, and with five or seven veins. The paleæ are enclosed by the fertile glumes, and resemble them except in being more delicate. On ripening, the fertile glumes and paleæ become hardened. Within them, in perfect florets, are two minute lodicules, three stamens with capillary filaments and versatile anthers, slightly bearded at the tip, and the ovary with a simple style crowned by two long stigmatic plumes.

The modifications undergone by diseased ears affect the secondary axes of the inflorescence only; and certain parts of these to a much greater extent than others. The following account is based on the dissection of some hundreds of spikelets from about forty diseased ears. Owing to the variation which I have found

between individual ears, it is more than probable that changes other than those described will be found on further search.

1. The bristles of the involucre are very often hypertrophied, the hypertrophy affecting some only of the bristles (plate II, fig. 4) These are enlarged into tough, simple spines, usually non-plumose, ribbed, and showing various degrees of longitudinal torsion. They may be one inch long, by one-sixteenth of an inch thick, and may be flattened, round or angular. The upper part is sometimes spirally twisted, corkscrew-like. The bristles are also transformed in some cases into leathery, brown, flattened or contorted bodies, but they never show any approach to a leafy structure.

2. The pedicel sometimes bears two spikelets, the lower being laterally seated and sessile, a little way above the involucre (plate II, fig. 3). Only two spikelets have been seen thus, arising from the one rachilla.

3. The number of florets on a spikelet is sometimes increased to three or four (plate II, fig. 3, upper spikelet). One or two of these may remain as mere aborted buds, usually at the lower part of the rachilla.

4. In the individual spikelets the lower glumes I and II are never altered. As in normal ears they are often minute, and the lower usually difficult to see, and sometimes suppressed. The succeeding glumes III and IV, with their enclosed paleæ, are sometimes unaltered. More usually they are elongated, sometimes to over an inch in length (plate II, figs. 2, 3, 5). They never lose their character as glumes, and no division into sheath and blade was observed in any case, though they are occasionally virescent and usually softer and more membranous, than normally. Torsion, particularly of the upper part, often occurs ; and sometimes the glume is split into segments as a result of a local action of the parasite, which will be more fully described under the leaf alterations to be mentioned below.

5. The lodicules are unaltered or suppressed.

6. The stamens are variously modified (plate II, fig. 6) or suppressed. The changes affect both the filament and anther.

The former may be prolonged to a length of over half an inch, or reduced, so that the anther is almost sessile. It may remain capillary, or become flattened and plumose, particularly at the base (e, g). The anther may remain unaltered on the modified filament, or may be reduced (e), elongated (c), plumose (d), or, rarely, contorted. The whole stamen may be changed into a leafy structure, colourless or brownish, narrow, with nearly straight sides, usually ciliate and sometimes with a transverse fringe, marking a division into a sheath-like and a blade-like portion (k, l, m, n). When thus flattened, the middle is often marked by a distinct vein (l). Sometimes the stamen appears as a brown, leathery, pointed body, with no differentiation into filament and anther, and almost circular in transverse section, thus becoming staminode-like. No increase in the number of stamens was observed.

7. The main alteration takes place above the stamens. The central portion of the floret is usually prolonged in diseased ears into a leafy shoot, consisting of reduced foliage leaves, much twisted or malformed (plate II, figs. 2, 3, plate III, fig. 2). This prolification occurs chiefly in the upper, perfect floret of the spikelet, but is accompanied usually by a similar, though less marked prolification of the lower, male or sterile floret. Sometimes the two are nearly equally affected. The maximum length observed in leaves thus axially produced within the stamens, was three inches, and the maximum breadth one quarter of an inch. Usually a well-marked division into sheath and blade occurs, the sheath being often more developed than the blade, which may be very imperfectly formed and much inrolled. The colour is either green or brown. A tendency to longitudinal shredding is often shown, a feature shared, as will be seen below, by the diseased normal leaves of affected plants. Longitudinal torsion occurs here also, and usually there is some degree of crinkling into longitudinal or transverse folds, particularly in the blade (plate II, fig. 2).

In place of a simple axial leafy shoot, the centre of the floret may be occupied by a branched reduced shoot with simple, soft, brown elements, crowded together in minute buds (plate III, fig. 1). This condition appears to be rare. An intermediate stage

occurs sometimes in the prolificated male florets, where the centre may consist of four or five small, brown, simple or branched elements enclosed by the paleæ. Some of these may be staminodes, but the central ones are more probably reduced shoots, as it is difficult otherwise to explain the branching.

Central prolification of the floral axis in plants may be of different kinds. It may be what is often described as viviparity. This term appears to be very loosely applied in teratology. Strictly speaking, it implies the germination of the seed while still attached to the parent plant. It is also employed to denote sprouting of the inflorescence buds under similar conditions. But it is used, especially in the case of grasses, to cover cases of virescence of the outer floral whorls, or of prolification of the floral axis below the gynæcium, conditions in which it is difficult to justify the terminology. Thus Penzig (1894, Vol. II, p. 465) uses it to specify two cases described by Toumey (1891) of malformation in *Phleum pratense*, in one of which the floral glume was prolonged into a leaf, and in the other the axis above the glumes was elongated, and bore at its apex a perfect flower. It appears probable that many cases of so called viviparity in grasses, belong really to the class of changes next referred to.

This is the form of central prolongation of the axis of the flower called by Moquin-Tandon "median prolification" ("diaphysis," Englemann). Two varieties of this are described by Masters (1862, p. 360). In one, the new growth proceeds from between the carpels, which are formed, though they may be much modified. In the other the carpels are absent. The new growth is usually a flower bud ("median floral prolification," "floriparous diaphysis"), but it may be a leaf bud ("median frondal prolification"; "frondiparous diaphysis"). Masters points out that the change occurs very frequently in such plants as normally show a tendency to prolongation of the floral axis, indicated, for instance, by their having, free central placentation, or an enlarged thalamus (Rosaceæ, Ranunculaceæ), or elongation of the axis between two of the floral whorls, as in Dictamnus. The prolification is therefore in Masters' opinion one, not of the pistil, but of the upper segment of the floral

axis, which may occur either above the carpels or may involve them. Two instructive cases are described by Masters in this paper. In one, a species of Campanula, the calyx was free, the corolla double, the stamens with petaloid filaments, and in the place of the pistil, there was a bud consisting of several series of green bracts, arranged in threes and enclosing quite in the centre three carpellary leaves detached from one another and the other parts of the flower and open along their margins where the ovules were placed. In the other, a Fuchsia, the calyx was similarly detached from the ovary simultaneously with the extension of the axis. Here the petals were increased in number and variously modified, the stamens also ; while in the centre and at the top of the flower, conjoined at the base with some imperfect stamens, was a carpel open along its ovuliferous margin. These cases indicate a lengthening of the floral axis, immediately below the gynæcium, and in the second case the stamens were carried up on the prolongation.

The axial sprouting in the florets of Pennisetum in this disease, is a case of median frondal prolification, and belongs to the second variety of this, mentioned above, *i.e.*, that in which the whole segment of the floral axis, which bears the pistil, is prolonged, the pistil being at the same time entirely suppressed. In no case examined, was any trace of the pistil to be found. Further two cases were seen in which the stamens were carried up on the prolificated axis ; in one, three stamens arose from the dorsum of the outer leaf of the new bud (plate II, fig. 7*a*) ; in the other, two of the stamens occupied their ordinary position at the base of the bud, while the third was carried up, and arose a couple of millimeters above the other, on the outer side of the sheath tube of the first leaf of the bud (fig. 7*b*).

In one head examined, the greater part of the florets were produced into an axial horn, a hollow organ entirely closed at the margin and produced from within the staminal whorl. This was, in many spikelets, produced equally from the lower (normally male) as from the upper (perfect) floret of the spikelet. Though, at first sight, it resembled a hypertrophied pistil, its structure was

that of a leaf, and it must be considered as merely a modification of the commoner form of median prolification, in which the bud consisted, instead of a leafy shoot, of a leaf united at the margins to form a tube, within which, at the base, the rudiments of a second leaf were often formed. Hairs and stomata occurred on both surfaces, within and outside the tube wall. In some cases the union of the margins was imperfect, only occurring at the base, while the top was an inrolled blade.

It must not be supposed that all these changes occur in each diseased ear. As a matter of fact, there is the greatest possible variation between one diseased ear and another. In some, the bristles alone are affected, in others, the glumes show the most marked alterations, while in others median prolification is almost universal in the florets.

Besides the ears, the leaves of plants affected with this disease show more or less considerable changes. In young plants, or in early stages, many leaves may be seen with the usual fresh green colour changed wholly, or in part to whitish, and later to brown. The whitening of young leaves is visible usually as long streaks, often occupying half or more of the leaf surface, in transverse diameter, and extending almost the whole length of the leaf. In older plants the leaves affected are chiefly those from whose axils the ear stalks spring. These are more completely whitened than in younger plants, and the colour rapidly changes to yellowish brown. At the same time the leaf is deformed, being twisted and transversely folded, and shows a great tendency to shredding of the blade towards the tip (plate IV, fig. 1). This shredding is also shown in plate IV, figs. 2, 3, in other plants affected with the same disease, but is not usually so evident in Pennisetum, as in these. In old plants, when the green ears are fully developed, the upper leaves are mostly browned, and many of them similarly split. Many leaf buds in branching stalks are contorted, a mass of small white or brown twisted leaves being enclosed within the contorted outer leaf sheath (plate IV, fig. 1).

A considerable number of cases of virescence, prolification, and other modifications of the flowers of plants is known to be the

result of insect or fungus attack. Many instances of the latter are mentioned by Tubeuf and Smith (1897, p. 26) and Rostrup (1886). Thus Peronospora violacea causes the stamens of Knautia arvensis to become petaloid. Ustilago violacea causes the rudimentary stamens of the pistillate flowers of Lychnis dioica to develop fully. The reverse occurs under the influence of several Ustilagineæ, ovaries developing in staminate flowers, as in Carex præcox infected with Ustilago Caricis. Physoderma deformans Rostr. causes virescence and malformation of the flowers of Anemone nemorosa. The extraordinary hypertrophies and distortions of the flowers of Cruciferæ attacked by Cystopus candidus are well known. Molliard (1901) has even shown that parasites acting at a distance can produce these modifications; as, for instance, in Primula officinalis, where double flowers result from the attacks of a Dematium on the roots; and petalody of the stamens of Scabiosa Columbaria was experimentally induced by him by inoculation of the roots with Heterodera radicicola.

In grasses, several instances of floral modifications of this nature are known, the most important of which are caused by fungus parasites of the genus Sclerospora, one of the Peronosporaceæ. It is to one of these that the disease just described is due.

The mycelium of the parasite is found in all parts of the attacked plants which show the alterations mentioned above. Thus it has been found in the stem, leaves, rachilla, bristles of the involucre, glumes and prolificated shoots.

The hyphæ are large, unseptate, very variable in size, up to nearly 10μ in diameter, and run chiefly intercellularly (plate IV, fig. 4). They are found in the ground tissues of the stem, and the mesophyll of the leaves chiefly, but branches penetrate the bundle sheaths in the leaves, where they lie between the sheath cells, and others collect under the stomata and in young leaves send out clusters of condiophores through these into the air. Only in rare cases, chiefly in late stages, have hyphæ been observed in the inner walls of the epidermal cells sending haustoria into them. The xylem and phloem elements proper never contain the fungus,

though in some of the distorted bundles, where it is difficult to distinguish between the sheath and the outer layers of the xylem, cells may occasionally be found, apparently lying in the xylem, containing hyphæ. These are really sheath cells, infolded into the xylem by the distortion of the whole.

As in the case of several other fungi whose habitat is chiefly between the cell walls, some branches penetrate the latter and pass into or across the cell cavity. These intercellular hyphæ are of two kinds. The one are similar to the haustoria of other Peronosporaceæ, being simple or branched, thin-walled processes, arising from intercellular hyphæ, and sometimes forming small fungal clumps within the cells (plate V, fig. 1). The others correspond to the "Verbreitungshyphæ" described by Guttenberg (1905) in Ustilago Maydis, and like them are thick-walled filaments, often clothed with a distinctly two-layered cellulose sheath (plate V, fig. 3). This sheath, as in the maize parasite, consists of an outer portion deposited by the host cells around the penetrating hypha, in a defensive attempt to check its growth. The attempt often succeeds and the resulting thick-walled pegs projecting into the lumina are not uncommon (plate V, fig. 4). The inner part of the sheath is the wall of the fungus filament itself.

The intercellular mycelium is sparse in the stem and attains its greatest development in the leaves. The hyphæ frequently occupy the intercellular spaces at the angles of the mesophyll cells, but are also found in the lamellæ between two cells. They branch freely, have thick, rather gelatinous, cell walls, and clear protoplasm. In the stem, haustoria are not common, and are chiefly small, often button-shaped, processes, not unlike those of Cystopus. Their full development occurs in the leaves (plate V, fig. 1). Here, they are often extraordinarily numerous and usually simple or branched finger-shaped processes, sometimes much convoluted and occupying a fair proportion of the cell cavity. Their wall is thin while young, but older ones often have distinct cellulose caps (fig. 2) which are possibly provided by the host plant after the organ has ceased to be active, as in the case of Cystopus candidus (Guttenberg, 1905, pp. 8 and 9).

In fully infected leaves the mycelium is collected chiefly between the cells of the mesophyll adjoining the bundles and also in the inner layers between these (plate III, fig. 3). When sporangium formation is about to begin, tufts of mycelium reach the air chambers of the stomata, which are, as in many grasses, arranged in parallel, longitudinal rows, one on each side of each vein. Sporangium formation is accompanied by great assimilative activity of the fungus, which so increases its demands on the living cells of the host, as to cause the latter to collapse and finally die. Prior to this, the chlorophyll of the assimilating cells is wholly or in part destroyed, and starch is noticeably absent in the cells which harbour the haustoria of the parasite. Hence the pale streaks, which are the first indication that young leaves are affected, are visible before any conidiophores are extruded, and these streaks only turn brown, from death of the cells, after sporangium formation has reached its maximum.

The effects of the fungus on the tissues are evident both in the mesophyll and the bundles of the leaf. The former undergoes hypertrophy ("hyperplasie," Küster, 1903), the number of layers being increased without any modification in the structure of the cells. These remain always large, thin-walled cells, with small air spaces in the angles between adjacent cells. In the sheath, where a hypoderm of a single layer is often demarcated from the mesophyll on the upper surface, this may be increased to two or three layers. In the blade there is no hypoderm, and the increase takes place in the ordinary mesophyll layers, but is never considerable and is sometimes absent. On the whole, it may be said that the fungus occurs in greatest quantity in the blade of the ordinary leaves, and in the sheath of those produced by median prolification, and the hypertrophy produced is most evident in these parts.

In the bundles, the number and size of both the xylem and phloem elements are increased. In normal bundles of moderate size, the xylem consists of a central spiral vessel, with a second (annular) vessel, or an air space, inside it, and two large lateral vessels, one on each side. The phloem consists of a group of

sieve tubes with their companion cells. In diseased leaves, the vessels are increased in size and number, groups of two or three large vessels occurring on either side (plate IV, fig. 4). The sieve tubes are increased in number and are slightly larger than normal. These modifications occur both in the sheath and blade of attacked leaves. From the collapse of the central layers of parenchyma which follows on sporangium-formation, and the consequent flattening of the leaf, the bundles are, in old cases, often distorted, being broadened transversely or sometimes infolded, so that the xylem projects laterally outside the phloem. In these cases the large vessels are flattened to a remarkable degree (plate IV, fig. 5).

Sporangia are produced only on the normal leaves of the host, never in the inflorescence. Following on the appearance of the whitish streaks which are the first outward sign of the presence of the parasite in the leaves, a cloud of thick, pale conidiophores bursts from the stomata, covering the surface of the streaks with a greyish white haze easily visible to the naked eye. A single or several conidiophores may project from each stoma (plate V, figs. 5, 6). They are broad, rather short, stalks, measuring about 100μ in length, by $12\text{-}15\mu$, unbranched in the lower part, but usually with a few short, thick branches, dichotomously or trichotomously formed at the top, and crowned with numerous papillæ of characteristic shape, on which the sporangia are borne. The latter are hyaline, broadly elliptical, slightly pointed at the free end, with a thin smooth wall, and $22\text{-}30\mu$ by $12\text{-}16\mu$ in diameter. They fall early without any stalk, and germinate rapidly in water, liberating zoospores (plate V, fig. 8). The number of zoospores varies with the size of the sporangium, from three or four up to a dozen or more. They are irregularly kidney-shaped, unequal sided, flattened bodies, with two cilia from the concave side, the posterior of which is the longer (plate V, fig. 8). The zoospores after coming to rest round off, measuring 9 to 12μ in diameter in the quiescent state, and germinate rapidly by a hypha.

After the formation of sporangia the conidiophores early collapse, the whole asexual stage of reproduction being evanescent, and only to be found in young plants. Once the characteristic

deformity of the ears is visible, sporangia are not likely to be found.

Oogonia are formed in immense quantity, at a late stage in the life history of the parasite.* After fertilization they are large brown bodies, visible from their size and colour to the naked eye. They occupy the parenchyma of the leaf blades, both of the foliage leaves and of those formed in the inflorescence. Very rarely they occur in the sheaths of the foliage leaves and in the glumes, while in contrast to the foliage leaves, the sheaths of inflorescence leaves often contain them. They are often arranged in longitudinal rows on each side of the veins, as a result of oogonium formation taking place chiefly in the layers of parenchyma bounding the bundles, where, as already mentioned, the mycelium shows a tendency to collect. The ripe oogonium after fertilization, thickens its wall, which is closely applied to the wall of the oospore without, however, fusing. Hence, the whole fruit is characterised by the possession of a very thick wall in two layers, the outer of which is the oogonial wall, and the inner only belongs to the oospore.

The oospore is usually perfectly spherical, with a smooth wall, yellow in colour (Saccardo's "Chromotaxia" No. 23), and of even thickness all the way round. The oogonial wall, on the other hand, is deeper in colour, approaching tawny (between Nos. 31 and 32 of Saccardo), and is often irregular, being provided with thickenings, which gave the whole fruit an elliptical, angular or irregular shape, according to their position, but prevent it being ever quite spherical. The ripe fruit (plate V, fig. 9) measures 34 to 52μ in diameter (average of 25 measurements, 42μ), the oospore proper being 22·5 to 35μ in diameter (average of 50 measurements 32μ). After trials extending over two years, I have not succeeded in germinating the spores, though from the evanescent nature of the asexual stage, and the regular manner in which the disease appears in certain places every year, it is highly probable that this occurs

* A rough calculation, made by counting the number of oospores in a measured part of the field of the microscope, gave 480 oospores to the square millimeter, in a portion of leaf where they were arranged in an almost solid mass.

freely in nature under suitable conditions. My trials have been made in the north of the Gangetic plain where I have never observed the disease to occur.

Three other examples of Sclerospora disease of cultivated Gramineæ occur in India.

The first of these is common in some places on Andropogon Sorghum (*jowar*), and I have collected it from several parts of the Bombay and Madras Presidencies. It is also the disease referred to in Madras by Mr. C. A. Barber (1904, p. 278), under the heading of "shredding of the leaves." Any disease of this most important crop which holds the possibility of epidemic extension, as this certainly does, is worthy of note.

It occurs frequently on low-lying land and does not appear to be easily detected on young plants. The affected plants become whitened at the top, irregular streaks forming in the upper leaves. Axillary branches are frequently deformed, a crowded bud being held imprisoned in the sheath of the subtending leaf, or the internodes are shortened so that the leaves stand out in a fan-like manner. Later on the usual shredding occurs, from destruction of the parenchyma between the veins (plate IV, fig. 2). At this stage, or earlier, the oospores are distinctly visible to the naked eye as small reddish points, arranged in parallel rows. These have been found in the leaf blades only, not in the sheaths. The ears may or may not be affected. In many cases they are not formed at all. In others they are deformed and much reduced but without the profound alterations of the flowers seen in the ears of Pennisetum. Mr. Barber says that in attacked plants no grain is produced. Hence, complete sterility is possibly a feature of this disease, though I have not had sufficient opportunity to examine this question personally. No sporangium formation has been discovered.

Anatomically the fungus occupies the leaf blade chiefly, having the same general distribution in the tissues as in Pennisetum. A dense fungus layer surrounds the bundles in advanced cases, lying outside the bundle sheath. In this the oospores are chiefly developed. The hyphæ are not usually as large as in Pennisetum and are hence more difficult to see. Similarly the haustoria are

less developed, those seen being chiefly simple finger-like processes entering the parenchymatous cells.

Excepting for the absence of a sporangial stage, the fungus agrees with that on Pennisetum. The oogonia are similar in shape and colour and measure 38 to 50μ (average 41μ), thus being slightly smaller than on the first host. The oospores are 27 to 33μ (average 32μ), thus agreeing with the other. I can find no constant difference sufficient to refer the fungus on the two hosts to different species.

The third cereal disease caused by a Sclerospora in India is very briefly referred to by Mr. Barber in the same paper as the above. It occurs on Setaria italica in Madras, being very abundant in some parts. I have only examined specimens kindly provided by Mr. Barber, and have not seen it in the field. These showed the same distortion and shredding of the leaves as in the previous cases (plate IV, fig. 3). The latter were crowded with oospores, agreeing with those on the other hosts in shape and colour, and 36 to 46μ (average of twenty measurements 41·5μ) and 26 to 34μ (average of twenty measurements 30μ) respectively, in diameter. Hence, though the asexual stage was not observed, the fungus cannot be separated from those on the other hosts.

The last of the Indian Sclerospora diseases which I have seen was found on Euchlæna (Rheana) luxurians on the Poona Government Farm, in 1905. The sporangial stage alone was observed, and agreed perfectly with that on Pennisetum which was common in the vicinity. Only early stages of the disease were seen, and hence oospores could not be discovered. The host plant was being experimentally grown on the farm and is not, so far as I am aware, cultivated anywhere in India, though an important fodder in some parts of the world. The disease is therefore of minor importance in this country.

The whole of the characters of these fungi correspond to the type of the genus Sclerospora. Of this three species have been recognized in the most recent work on the genus, and a fourth should probably be added, to include Peronospora Maydis Raciborski (1897). Thus extended, it embraces all the Peronosporaceæ which

occur on grasses, and all of its members are found on these hosts, excepting the least studied, S. Magnusiana Sorokin, which was found by Sorokin on Equisetum in Russia.

Peronospora Maydis Racib. agrees entirely with Sclerospora in its asexual stage, differing from all other Peronosporaceæ in the broad, short conidiophores, with short, thick, dichotomously formed branches at the top, provided with broadly conical papillæ on which the conidia are formed. The mycelium and haustoria also agree, the latter being of the button-shaped type found in the stem of Pennisetum. The oogonia differ somewhat, having a not very thick, though persistent, membrane. This is not smooth, but provided with irregularly arranged, small, conical, warty thickenings. In the older descriptions the oogonial wall of Sclerospora was described as fusing with that of the oospore on ripening, but Berlese (1902, p. 69) is clearly not of this opinion, and it is easy to ascertain from sections or by long maceration that the two coats are perfectly distinct. In Raciborski's species therefore, the separation of the two walls mentioned by the author does not tell against the fungus being a Sclerospora. No doubt the figure accompanying the description is about as unlike the oospore of a Sclerospora as could be, but it is evidently highly diagramatic, and omitting the figure, the description would apply sufficiently to Sclerospora. In Berlese's Monograph it is also suggested that the species is a Sclerospora, but a definite opinion is not given there, and cannot be given here, in the absence of an examination of original specimens. The fungus causes the most intense cereal disease produced by the Peronosporaceæ, epidemic outbreaks in Java (where it is known as "lijer"), destroying whole fields of maize. It has not so far been reported elsewhere.

The remaining grass parasites of the genus have been critically examined recently by Traverso (1902 (1)). As a result of a careful study he gives the following classification, reducing to two the three species which had been usually accepted:

Oospore 28-35μ. d.; hybernating spore with undulated contour, with wall of the oogonium very thick, rubiginous. *Scl. graminicola.*

Oospore $40\text{-}60\mu$. d.; hybernating spore with smooth contour, with oogonial wall not or little thicker than that of the oospore, pale yellow. *Scl. macrospora.*

As an asexual stage has only been found in Scl. graminicola, Traverso bases his classification on the sexual stage alone. It is in this stage only, that the majority of students of the genus have seen their species.

Sclerospora graminicola (Sacc.) Schroet. has been recorded up to the present only on species of Setaria, chiefly S. viridis, but also S. italica, S. glauca and S. verticillata, in Italy, France, Germany, Austria, Russia, the United States and Japan. The influence of the parasite is very similar to that above described, virescence of the ears and distortion and shredding of the leaves being common. An excellent illustration of the disease of S. italica ("Awa") in Japan is given in Arata Ideta's Lehrbuch der Pflanzenkrankheiten in Japan (1903) with a description in Japanese. In this, the prolification of the spikelets and shredding and torsion of the leaves is well shown, and the fungus is clearly figured. It will be remembered that this is one of the cereals mentioned above, as being subject to Sclerospora disease in India. Similar effects on the other host plants have been referred to by several authors.

Sclerospora macrospora Sacc., under which Traverso, apparently with good reason, includes Scl. Kriegeriana Magn. (1895) occurs on a number of grasses, having been found in Australia on Alopecurus sp.; in Germany on Phalaris arundinacea; in France on oats; and in Italy in recent years, on wheat, maize, oats, Avena fatua, Agropyrum repens, Glyceria maritima (?), Phalaris coerulescens (?), Ph. arundinacea (?), Ph. canariensis, Lolium perenne, Agrostis alba (?), Holcus mollis (?) and Phragmitis communis. Its conidial stage has not been discovered. The Italian species, which was, after critical study, referred to this species by Traverso, was first considered by Peglion (1900 and 1901), who had chiefly investigated it in the field, to be Scl. graminicola. In the neighbourhood of Rome in 1899 a rather severe outbreak occurred in wheat, due chiefly, according to Peglion, to flooding of the fields by the Tiber in that year. The

ears were deformed and virescent, and no grain was matured in affected plants. The disease on this host has been several times observed since in different parts of Italy. A similar disease of maize was described by Cugini and Traverso (1902) near Modena, and its effects on this host as described by D'Ippolito and Traverso (1903) are similar to those of Scl. graminicola on Setaria. On the other cereal hosts mentioned above, the damage caused appears to be less considerable, and outside of Italy these new cereal diseases, which nevertheless are threatening enough, appear to have attracted little notice.

In the tropics I have been able to find only two references to disease produced by the genus, leaving out the "lijer" disease of maize. In neither is the parasite correctly determined. One is that by Mr. Barber (1904) mentioned above; the other a brief description of a Pennisetum disease, similar to that in India, from specimens collected by Dr. W. Busse in German East Africa, by F. C. von Faber (1905). In the first of these the parasite is taken to be probably one of the Chytridiaceæ, since the mycelium was not clearly seen, and the sporangial stage not observed. The resemblance of the oogonia to the resting sporangia of some Chyridiaceæ is considerable. In von Faber's paper the mycelium and oospores are described but not the sporangial stage, and the author was unable to determine if the Chytridiacean-like bodies (the oospores) were in organic connection with the mycelium, and attributes the disease to the mycelial infection. His description of the pathological changes in diseased plants differs somewhat from that given above. The glumes and bristles of the ear are said to be prolonged into leafy structures, a condition never seen in my specimens, and in the latter case difficult to accept on morphological grounds. The leaves are thickened by the development of a many layered hypoderm. Since, however, I have found a wide range of variation in the character of the deformity produced in different ears, it is quite possible that the action of the parasite in Africa differs from that in India. There appears to be no reason for supposing that the diseases are different.

It remains only to determine the species to which these Indian Sclerospora parasites belong. After a careful examination of all my material and comparison with the specimens of Scl. graminicola issued in Sydow's Phycomycetes and Protomycetes (Nos. 36, 37 and 165) and Scl. macrospora issued in Briosi and Cavara's Funghi parassiti No. 352, no doubt remains that the Pennisetum parasite is Scl. graminicola. This is somewhat surprising when we consider the much wider range of hosts in Scl. macrospora, while this is the first time that Scl. graminicola has been found on other hosts than Setaria. The sporangial stage agrees fully with that already described in Germany by Schröter (1879) and Fischer (1902), and in Japan as figured by Arata Ideta (1903), though the sporangia are larger, being 22-30μ by 12-16μ as against 20 by 15-18μ (Fischer). The sporangia are, however, variable bodies, since Berlese (1902) quotes measurements by Malbranche and Letendre, giving 12-15 by 10-11μ as the diameter. Scl. graminicola is so far the only species known to have this stage, if we omit Peronospora Maydis.

The hybernating spore also agrees. Traverso (1902 (1)) gives a very full description of the fruit and finds from a number of measurements that the oogonium averages 45·9μ in diameter and the oospore 32μ. The measurements given above for the Pennisetum parasite (42μ and 32μ respectively) agree in the most important item, the oospore, and are much smaller in both than the corresponding measurements for Scl. macrospora. The specimens in Sydow's exsiccata collected by Sydow on Setaria glauca near Berlin (No. 36) and by Kabat on S. viridis in Bohemia (No. 165) agree in measurements, and in the colour and shape of the fruit, very closely with the Indian fungus. Excepting, therefore, the difference of hosts the Setaria and Pennisetum Sclerosporas agree in all respects.

The fungus on Andropogon Sorghum corresponds with the above in the oogonial stage, which alone has been found. It is, of course, possible that sporangia will be found on this host also, when it is more fully examined, as I have not had sufficient opportunity for watching it on the living plant. In all the systematic

works which treat of Sclerospora the characters of the ripe fruit are taken as the basis for classification, and on this basis it is impossible to separate the species from Scl. graminicola.

On Setaria italica similarly, only oogonia and oospores have been observed in India. These are identical with the above in shape and colour, and are almost exactly the same size. As Scl. graminicola is already widely known on this host, this merely adds a new locality for its ravages. Traverso (1902 (2)) has found a special form. Scl. graminicola var. Setariæ italicæ—in Italy, differing from the type, in having larger oogonia and oospores ; but the fungus in India agrees in all respects with those on other Setariæ in Sydow's exsiccata and from the measurements given must be referred to the type species, not the variety.

Finally the fungus on Euchlæna luxurians agrees in its asexual stage with Scl. graminicola and, as no other species is known to possess this stage, may be referred provisionally to it.

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PUSA,
12*th February*, 1907.

E. J. BUTLER.

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DESCRIPTION OF THE PLATES.

Plate I.

General appearance of ears of Pennisetum typhoideum affected by Sclerospora graminicola (Sacc.) Schroet.

Plate II.

Effects of the fungus on the inflorescence of Pennisetum typhoideum.

Fig. 1. Normal spikelet of Pennisetum: 1. lower sterile glume; 2 upper sterile glume; 3 and 4 fertile glumes. P. paleæ. The upper floret is perfect, the lower male. X 7.

Fig. 2. Spikelets showing prolification. Figures and letters as before. X $1\frac{1}{2}$.

Fig. 3. Pedicel with two spikelets arising above the involucre. That on the right and lateral bears two florets, f. l. the lower, f. 2 the upper. That on the left and terminal bears three florets, f. 3., f. 4. and f. 5., 1. 1. lower sterile glumes; 2. 2. upper sterile glumes; 3. 3. 3. 3. 3. fertile glumes; P. P. P. P., paleæ; the floret, f. 3. being without a palea. s. s. s. s. s. the axial leafy shoots in the centre of each floret. These consist of a small number of narrow leaves, inrolled and contorted. X $1\frac{1}{2}$.

Fig. 4. Hypertrophied bristles of the involucre. Natural size.

Fig. 5. Modified glumes from affected spikelets. Natural size.

Fig. 6. Modified stamens from affected spikelets. See text pp. 3 and 4 for further description. X 2.

Fig. 7. Stamens carried up on the prolificated shoot. Natural size.

Plate III.

Fig. 1. Apex of the floral axis of an affected spikelet, consisting of a cluster of bud-like structures on a branched stalk. X 16.

Fig. 2. Dissection of two spikelets borne on one pedicel, as in Plate II, Fig. 3. i involucre of unaltered bristles; 1. and 2. lower and upper sterile glumes; 3. fertile glumes; P. paleæ, there being

none on two of the florets ; st. stamens variously altered, and with two suppressed in the floret on the right ; s. prolificated shoots arising within and above the staminal whorl. In the left hand floret this was a simple horn. In the others it consisted of some contorted reduced leaves, which have been in part dissected out in the two right hand florets.

Fig. 3. Diagram showing the position occupied by the fungus mycelium in the mesophyll of the leaf of Pennisetum.

Plate IV.

Fig. 1. Contorted leaf bud of Pennisetum typhoideum affected with Sclerospora.

Fig. 2. Leaf shredding in Andropogon Sorghum affected with Sclerospora.

Fig. 3. Leaf shredding in Setaria italica affected with Sclerospora.

Fig. 4. Section of an infected leaf of Pennisetum showing the distribution of the fungus hyphæ in the mesophyll and adjoining the bundle sheath.

Fig. 5. A leaf bundle distorted as a result of the action of the parasite in causing collapse and flattening of the mesophyll cells.

Plate V.

Fig. 1. Haustoria of Sclerospora graminicola in the mesophyll cells of an infected leaf of Pennisetum. On the left simple and branched finger-shaped haustoria, the type which predominates in the leaf. On the right two club or button-shaped haustoria, a type more commonly seen in the stem. X 500.

Fig. 2. Old haustoria with a distinct cellulose cap. X 500.

Fig. 3. Intracellular hypha, showing the wall of two layers, the outer of which connects with the cell wall and belongs to the host plant. X 500.

Fig. 4. a. Intracellular hypha running obliquely across two cells. Note the very thick wall and almost occluded lumen ; b. b. peg like processes projecting into the cells, but arrested in further growth by the deposition of a thick cellulose cap. X 500.

Fig. 5. Conidiophores of Sclerospora graminicola from Pennisetum after the sporangia have fallen, showing the mode of branching. X 400.

Fig. 6. Conidiophores bearing immature sporangia. X 400.

Fig. 7. Conidiophore with mature sporangia. X 400.

Fig. 8. Sporangia germinating after having fallen into water; and zoospores. From Pennisetum. X 500.

Fig. 9. Oogonia and oospores of Sclerospora graminicola, after ripening: a. from Pennisetum typhoideum, b. from Andropogon Sorghum; c. from Setaria italica. Optical section, diagrammatic. X 550.

PLATE II.

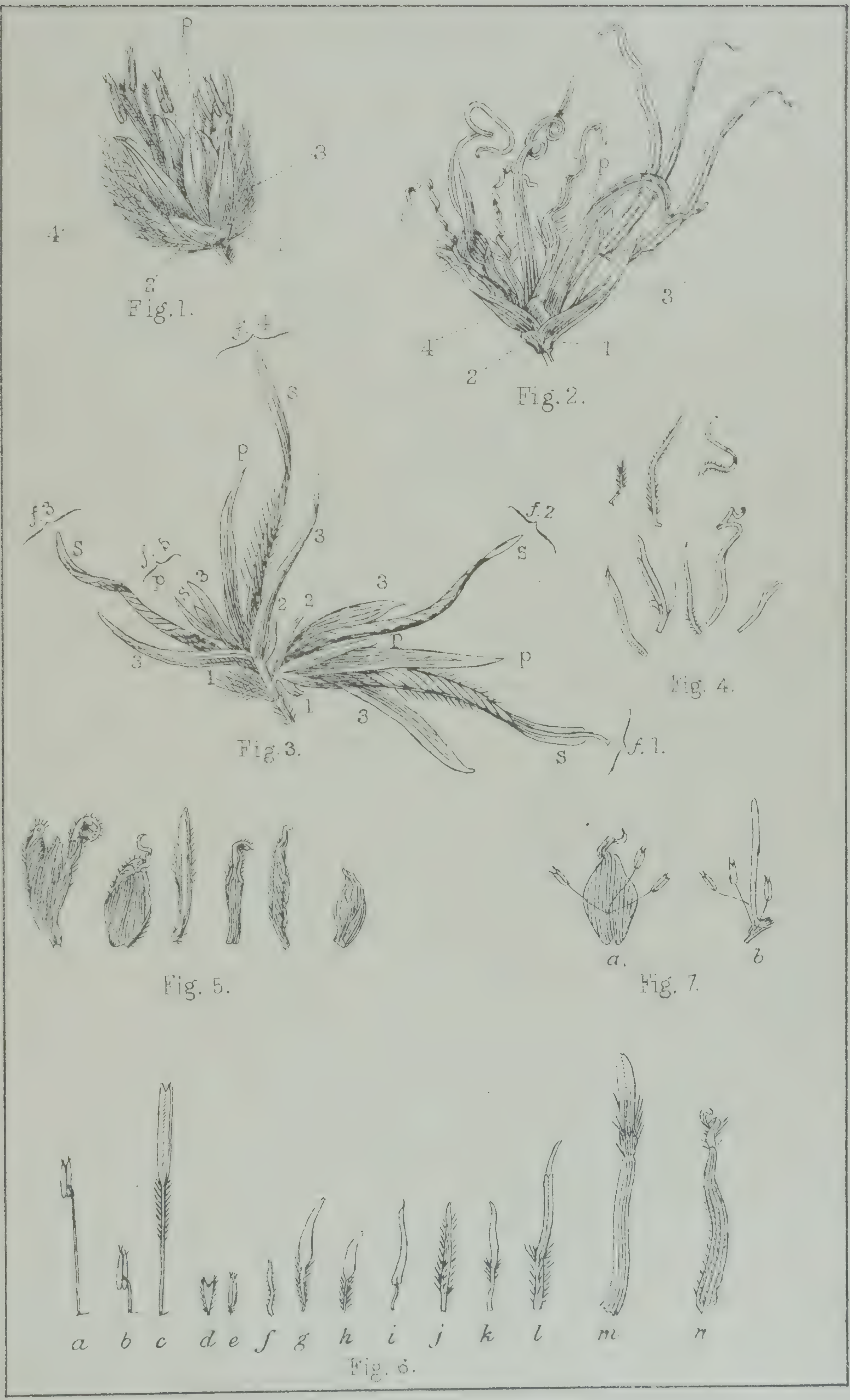


PLATE III.

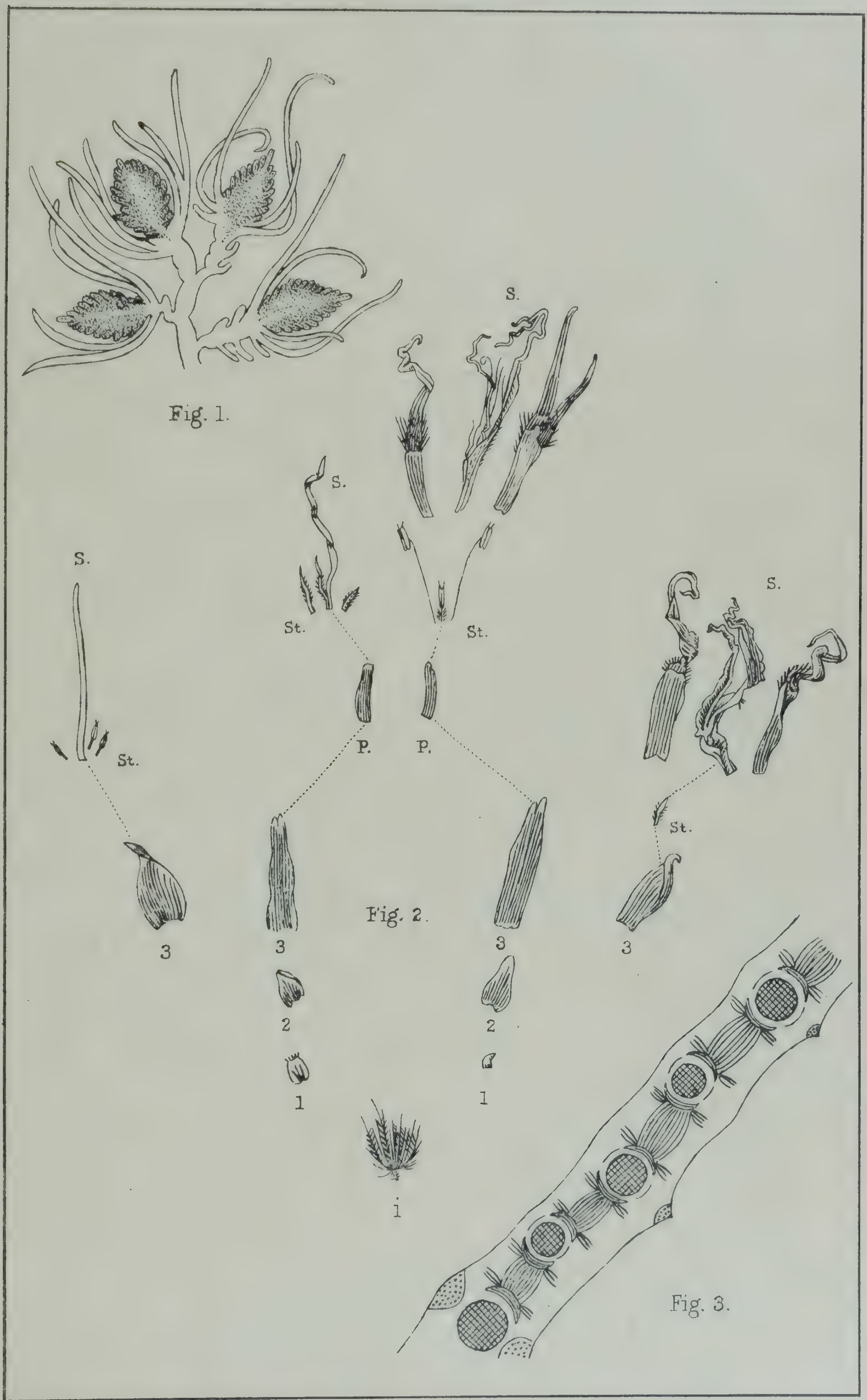


PLATE IV.

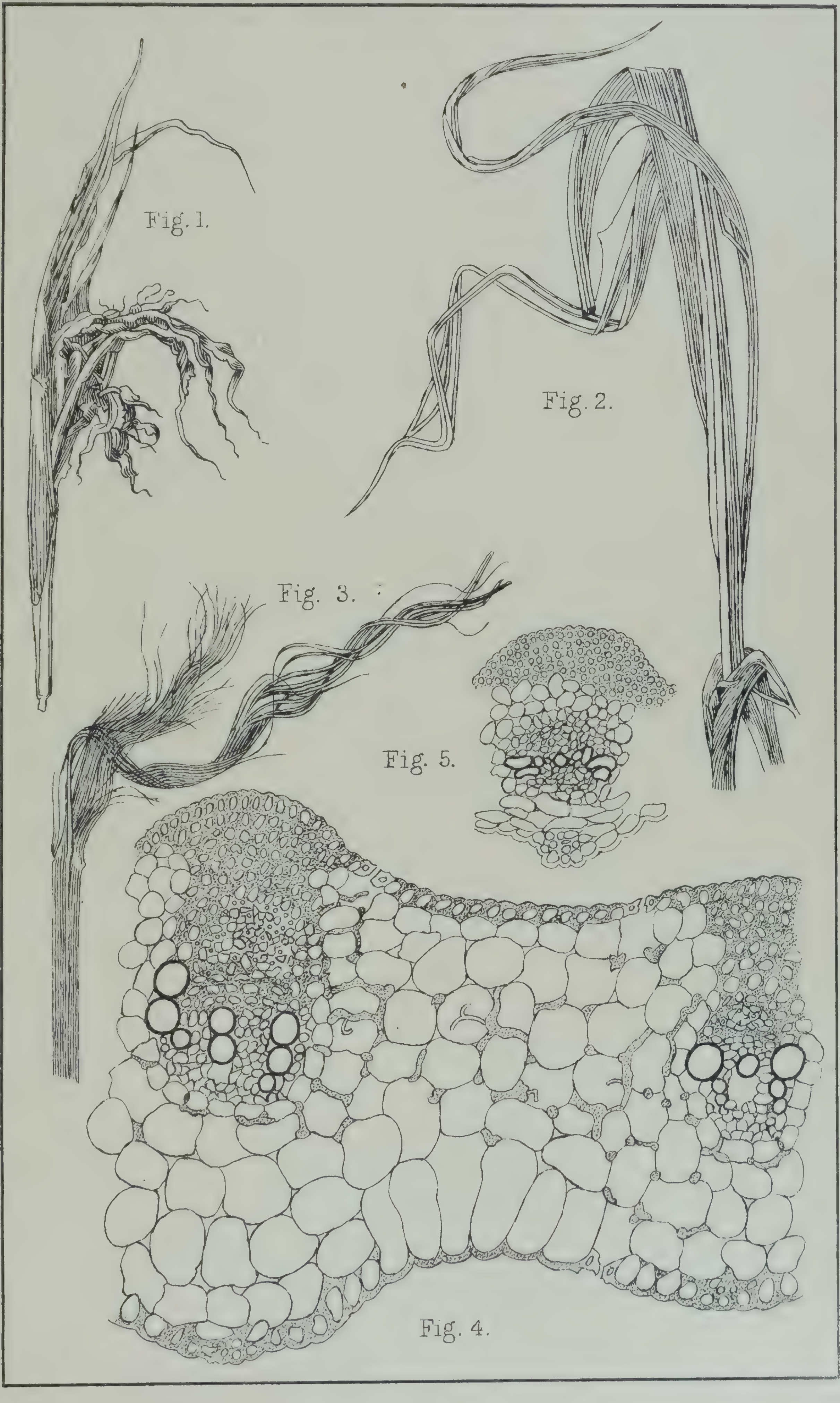
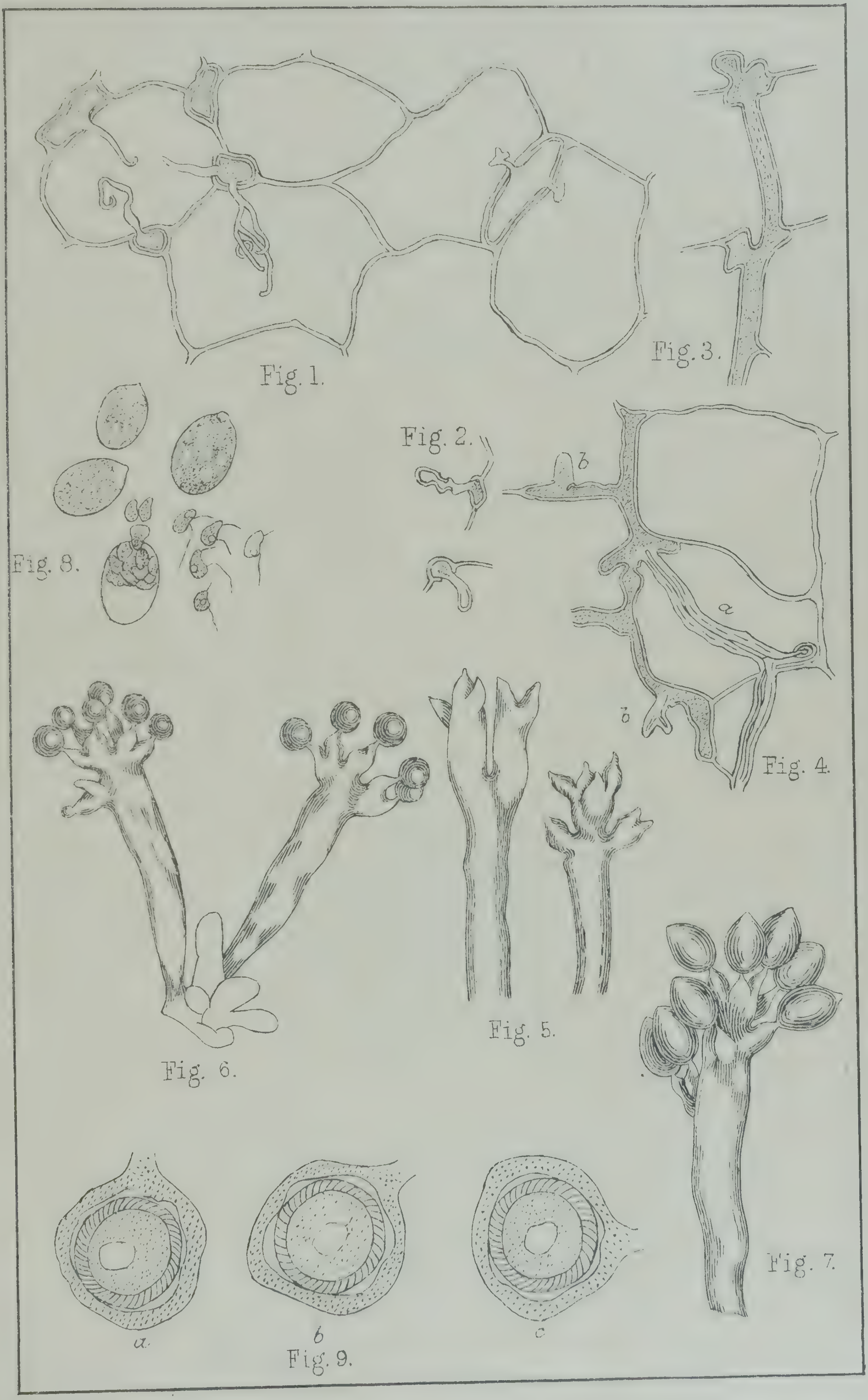


PLATE V.



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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA.

THE INDIAN COTTONS.

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THE INDIAN COTTONS.

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CHAPTER I.

GENERAL REMARKS.

The cultivated cottons of India possess the following characters in common. Erect, large or small shrubs, with long tap roots and few lateral roots. *Stems* woody and brittle below, herbaceous toward extremities, usually wandlike; growth cymose from the first so that the whole plant forms a *Sympodium;* inner bark of long tough fibres. *Branches* ascending or spreading, becoming successively shorter upwards, their disposition affording valuable diagnostic characters; all young parts except the flowers, covered with partially deciduous, hirsute, simple and stellate hairs. *Leaves* membranous or subcoriaceous, varying from entire to 1- 3- 5- 7-lobed, palminerved, margins of lobes entire or sinuate; accessory lobes often rising from or above the sinuses; the central rib and usually the rib on either side of it with a *gland* on the under surface. *Stipules* falcate, entire or toothed. (The leaves of seedlings and those appearing during the rainy season are larger, more flaccid, with more distinct basal lobes, folds and sinuosities than those which are developed after a partial shedding in the cold weather. *Inflorescence* cymose, of single flowers on terminal or secondary and tertiary axes, erect or spreading, always pendulous in fruit; *peduncle* and *pedicel* short, trigonous; *involucre* or *epicalyx* of three bracteoles connate at their broadly cordate bases, margins rounded, with deep or shallow teeth, which either extend over the whole margin or are confined to the apex, which

is obtuse or acute, venation longitudinally sub-parallel. *Calyx* gamosepalous, campanulate or cupular, *limb* entire or irregularly toothed, accrescent and usually splitting in fruit, with three *glands* often secreting a nectar-like exudation at the base externally. *Corolla* polypetalous, *petals* 5, contorted dark purple, pink, yellow or white with a dark eye, straight or reflexed, adnate to the base of the *andrœcium*. *Stamens* indefinite, monadelphous, lower part of the tube usually naked, upper part (exclusive of the very apex) with one-celled *anthers* on short erect or spreading *filaments*. *Ovary* superior, syncarpous, 3-4-celled, *ovules* numerous on axile *placentas*, lower part of *style* entire, the upper exserted part of 3 to 4 more or less connate and twisted arms bearing the stigmatic surfaces. *Capsule* or *boll* usually 3- but sometimes 4-celled, almost spherical or ovoid, subtrigonous acuminate, the point consisting of the short, persistent basal part of the style; *dehiscence* loculicidal, *valves* strongly reflexed so that the cotton becomes pendulous. *Seed* with a hard testa and spiny hilum, naked or covered with short down called fuzz or velvet and longer unicellular twisted, white or tawny hairs which constitute the cotton of commerce.

It is customary amongst botanists to assume that the numerous forms of cotton plants have become inextricably complicated and difficult to understand and distinguish through hybridization. After seven years of almost constant observation of a large series of Indian cottons grown in parallel plots in one block on the farm at Poona, I consider that this position is untenable and select the following facts to support my contention that Indian cottons are normally self-fertilized. A large number of varieties procured from almost every part of the country has been grown in contiguous lines without hybridization occurring. Although a number of hybrids has been artificially produced, not one of these can be matched with any known variety. The stigmas are usually pollinated immediately on the opening of the flower which, moreover, remains open for a very short time. Bees and small flies are fond of visiting the glands *outside* the calyx for the sake of the nectar; some beetles eat the petals; but few insects enter the

flower itself before it is fertilized. The results of a long series of experiments conducted by Mr. S. V. Shevade show that emasculated flowers allowed to remain uncovered usually drop off unfertilized. In the few cases where he observed that pollen was carried to the stigmas by insects, bolls were not subsequently developed. These observations are confirmed by the experience of Mr. F. Fletcher, M.A., B.SC. (Deputy Director of Agriculture, Bombay), in Egypt and India. Many of the varieties grown in India are separated by long distances, in which cases hybridization is, of course, a physical impossibility. In districts where a mixture of varieties is habitually grown by the cultivators, no hybrid plants are to be found. The progeny of plants which are artificially cross-fertilized are usually more fertile than their parents. This proves that cross-fertilization is really of great service to the plant. The form of its flower with a dark base is an ideal insect lure, and it is difficult to understand why cross-fertilization should not prevail. The only solution to the problem appears, therefore, to lie in the fact that, in the Indian cottons, these so-called species and hybrids are merely cultivated races, evolved by time and environment from one prototype. All the evidence available to me appears to prove, almost without the probability of a doubt, that *Gossypium obtusifolium*, Roxb., the *Rozi* of Gujarāt, the most widely distributed wild and cultivated cotton in the old world, is the parent from which all our present forms have sprung. The progeny from the plants of this species grown in Poona for seven years now show characters which bring it into close relation with *G. herbaceum* and *G. indicum*. In the field it is easily distinguishable as a species by habit alone, but I find it very difficult to separate it with certainty from *G. herbaceum* or *G. indicum* in the Herbarium. The bracteoles, which are relied upon as diagnostic characters, are also misleading as they are indifferently toothed or entire in flowers from the same plant. *Gossypium Stocksii*, a wild plant of Sind, is by some considered the parent stock of Indian cottons. I cannot concur in this opinion. It resembles no Indian cotton and possesses certain characters which induce me to surmise that it is a degeneration of some American cotton.

No species cultivated in Sind at the present time resembles it in any particular.

All Indian cottons can be hybridized freely by artificial means. Hybridization of American and Indian varieties has been invariably unsuccessful both in India and in America.

A few more years of experiment and observation are necessary to prove absolutely that climate, soil and general environment are the factors which influence the tendency to variations in the cottons. If botanists and agriculturists will devote careful attention to the cottons growing in the fields throughout their provinces, a confirmation or refutation of my theory will soon be arrived at.

CHAPTER II.

A PROPOSED CLASSIFICATION OF THE INDIAN COTTONS.

THE following classification is suggested after a close study (extending over seven years) of numerous varieties grown systematically at the Poona Farm, supplemented by field observations in the cotton districts of Bombay and by information generously supplied by observers in other parts of India. This season the United States Department of Agriculture has supplied me with seeds of a long series of American forms, and I defer attempting to compile a history of the nomenclature of the cottons until I have studied these in a living state.

No method adopted in any of the numerous works extant on the Systematic Botany of the whole or parts of India has been found to meet the requirements of our present knowledge. Three years ago I worked at the subject in England and found but little enlightenment, as the material in the Herbaria is not only scanty but has never been critically examined. Parlatore's work, entitled "Le Specie dei Cotoni descritte" and that of Todaro called "Relazione Sulla Cultura dei Cotoni in Italia seguita da una Monagraphia de Genere Gossypium" are the two principal works dealing with the botany of cotton. In default of

anything better I have attempted to correlate Todaro's descriptions and figures with our plants.

As these notes are drawn up primarily for the use of Indian agriculturists, I have multiplied the number of species and varieties, knowing from my own experience that such a procedure assists to simplify what even then must still remain a subject difficult to understand. From a botanical point of view it is clearly evident that we have at the most only one true species of cotton in India, *Gossypium obtusifolium*, with its two sub-species, *G. arboreum* and *G. herbaceum*. All other forms should be treated as derivatives of these. The following species and varieties which I describe are really agricultural races, which remain fairly constant to their characters in the environment within which they have been evolved or cultivated for some considerable time. Sharing in the same descent, they are capable of being crossed with facility and their descendants are fertile.

A. Rozi and Dev Kapas Group, all the branches ascending and thickly crowded, not drooping at their extremities. *Leaves* with basal lobes and lateral folds in the sinuses. *Bracteoles* entire or only slightly toothed on the margins and apex. *Flowers* small, dark purple, pink purple or yellow. *Bolls* small or large.

1. Gossypium obtusifolium, *Roxb.*—Whole plant green. *Corolla* yellow. *Cotton* white.

,, ,, ,, *Var. nov.* Coconada. *Cotton* drab.

,, ,, ,, *Var. nov.* hirsutior. *Plant* more hairy, with a strong tendency towards *G. herbaceum.*

,, ,, ,, *Var.* Nanking. *Plants* with a tendency towards *G. neglectum. Bolls* and *bracteoles* large.

1. Gossypium obtusifolium, *Roxb.—Var. nov.* sindica. *Branching* more sparse than in type, upper branches with a strong tendency to become successively shorter. *Plants* with a tendency towards *G. indicum.*

2. Gossypium arboreum, *Linn.*—Perennial. Whole plant and corolla dark purple or red. Velvet of seeds green. Lobes of leaves narrow.
 ,, ,, ,, *var. nov.* platyloba. Lobes of leaves broad.
 ,, ,, ,, *var. nov.* vagans. *Lint* khaki.

3. Gossypium sanguineum, *Hassk.*—Annual. Plants dark purple. *Corolla* dark purple.
 (*a*) broad lobed forms.
 (*b*) narrow lobed forms.
 ,, ,, ,, *var. nov.* minor. *Corolla* pink purple.
 (*a*) broad lobed forms.
 (*b*) narrow lobed forms.

B. Herbaceum Group.—Bushes round-headed or with the apex of the stem slightly prolonged and sparsely branched. All the branches usually long and spreading *Leaves* softly hairy, light green, folds lateral only in the sinuses. *Bracteoles* round, uniformly gashed, usually spreading in fruit. *Flowers* yellow with a dark eye. (The eye in the corolla of *herbaceum* varieties shows a yellowish white circle in the centre, from which arises the staminal tube and style. This circle throws out obliquely radiating yellow narrow bands or patches unoccupied by the dark crimson of the

eye. In other types this circle is represented by a perfectly regular pentagon, having no radiating yellow lines).

4. Gossypium herbaceum, *Linn.* *Valves of boll* thoroughly reflexed so that the cotton is pendulous.

" " " *var. nov.* madraspatana. With smaller bolls but otherwise as in type, of which it is probably a degenerated form.

" " " *var. nov.* melanosperma. As in the last, but testa of seed naked.

" " " *var. nov.* sakalia. *Bolls* large, not opening widely.

C. The Jethia Group.—Round-headed bushes, apex of stem seldom produced, branches ascending more sharply than in *G. herbaceum.* *Leaves* dark green, with lateral folds and rarely basal lobes in the sinuses. *Bracteoles* sub-triangular, gashed on the whole margin or more or less entire, not spreading in fruit.

5. Gossypium intermedium, *Todaro.* *Flowers* yellow. *Bracteoles* deeply gashed.

" " *var. nov.* alba. *Flowers* white. *Bracteoles* often entire. A link with *G. neglectum.*

D. The Bani Group.—Tall sparsely branched plants. *Lower branches* long slightly ascending, median and upper sparse, short, more or less drooping, becoming successively shorter, apex of simple stem much produced. *Leaves* yellowish green, entire to 3-lobed usually, lobes broadly ovate. *Bracteoles* triangular, entire or slightly toothed upwards. *Petals* reflexed, yellow or white. Cotton scanty and fine in the most typical examples.

6. Gossypium indicum, *Lamk.* *Flowers* yellow.

" " " *var. nov.* Mollisoni. *Flowers* white.

E. Jari and Varhādi Group.—Tall sparsely branched plants. *Lower branches* long, slightly ascending, median and upper sparse, more or less drooping, becoming successively shorter, apex of simple stem much produced. *Leaves* dark green, strongly heliotropic. *Bracteoles* triangular, entire or slightly toothed upwards. *Petals* reflexed, yellow or white.

7. Gossypium neglectum, *Todaro var. nov.* vera. Lobes of leaves narrowly oblong, base not deeply cordate. *Flowers* yellow. *Cotton* copious and coarse.

,, ,, ,, *Sub. var. nov.* kathiavarensis. Lobes of leaves broad, ovate-oblong. *Cotton* moderately fine.

,, ,, ,, *Sub. var. nov.* malvensis. Habit of type; but *Cotton* of superior quality.

,, ,, ,, *Sub. var. nov.* bengalensis. Lobes of leaves narrow, radiating. *Bolls* and *bracteoles* larger than in type. *Cotton* coarse.

,, ,, ,, *Sub. var. nov.* Kokatia. As in the last, but lint drab coloured.

,, ,, ,, *Sub. var. nov.* burmanica. As in *bengalensis*, but lobes of leaves broad. *Lint* white.

,, ,, ,, *var. nov.* rosea. Lobes of leaves narrow. *Flowers* white. *Cotton* coarse.

7. Gossypium neglectum, *Todaro. Sub. var. nov.* cutchica. Lobes of leaves broad, ovate-oblong. *Cotton* moderately fine.

,, ,, ,, *Sub. var. nov.* avensis. Lobes of leaves broad. *Bracteoles* and *bolls* larger than in type.

F. Kil Group.—Low plants. Lower branches drooping, upper becoming successively shorter. *Leaves* dark green, with narrow, radiating lobes. *Bracteoles* large, triangular, acuminate, entire or only toothed at apex, longer than the flowers, reflexed in fruit. *Flowers* normally white. *Bolls* usually large.

8. Gossypium cernuum, *Todaro. Cotton* white.

,, ,, ,, *var. nov.* silhetensis. *Cotton* drab.

G. Dharwar American Group.—Low rounded bushes. *Leaves* rather membranous, yellowish green, simple to 5-lobed, usually 3-lobed, lobes short, triangular, with straight margins. *Bracteoles* rounded with caudate acuminate teeth. *Flowers* light yellow, without a dark eye. *Bolls* large spherical.

9. Gossypium hirsutum, *Mill. Cotton* white.

,, ,, ,, *var.* rufa, *Todaro. Cotton* drab.

1. Gossypium obtusifolium, *Roxb. Fl. Ind., III.*, 183 ; G. herbaceum, *Linn* var. obtusifolium (*Roxb*). *Masters in Fl. Br. India,* I, page 347 ; G. Wightianum, *Todaro, Osser sui Cotoni,* page 47. Attaining the height of 7 feet and upwards. *Stems* robust, internodes short, all the branches acutely ascending and crowded. *Branches* dark red, with close, very short, stellate hairs mixed with longer, simple pilose hairs as are also the petioles and leaves. *Leaves* small, standing on the same plane as the petiole or at right angles to it, yellowish green with a distinct red blotch at base, 5-lobed, lobes ovate, rather obtuse mucronate, sinus broad or narrow, with a small extra lobe or fold, margins of some of the larger leaves sinuate. *Stipules* rather short, lanceolate, falcate.

Peduncles 1 or 2, on secondary and tertiary divisions, reflexed, trigonous. *Bracteoles* $\frac{3}{4}$ to 1 inch by $\frac{5}{8}$ to $\frac{7}{8}$ inch, ovately triangular acute, teeth rather shallow and acute, usually confined to the upper third but occasionally present on the whole of the margins. *Calyx* loose, campanulate, truncate or minutely 3-toothed, with three distinct glands on the base externally. *Corolla* up to $1\frac{3}{4}$ inch long, yellow with a dark eye, fading red. *Stigmas* united, slightly twisted. *Bolls* $1\frac{1}{8}$ to $1\frac{1}{4}$ inch by $\frac{3}{4}$ to $\frac{7}{8}$ inch, long pointed when 3-celled, short pointed when 4-celled. *Cotton* scanty, moderately fine and curly, *seeds* with a greenish gray velvet.

Indian Forms.—Rōzi or *Jaria*, a perennial growing for 6 or 7 years, cultivated on the light soils of Gujarāt. Professor Middleton says that it readily runs wild and in hedges assumes a climbing habit and then the cotton turns yellow and very short in the staple, the velvet at the same time becoming long; that it strongly resembles *G. arboreum*, the chief difference being a yellow flower and the absence of the marked reddish tinge possessed by that species.

Nadam. Madras. Mr. Benson, M. R. A. C. (late Deputy Director of Agriculture, Madras), says that Nadam and Bourbon are the crops of the lighter and more gravelly soils.

G. obtusifolium, *Roxb. var. nov.* Coconada. This differs from the type in having drab instead of white cotton. Mr. Benson says that the centre of trade in this cotton is at Gūntur.

G. obtusifolium, *Roxb. var. nov.* hirsutior. Plants more hairy, leaves larger and altogether with a strong tendency towards *G. herbaceum.*

Two forms have been received from Baluchistan under the names of *Keehi Kapās* and *Karpās.* I place these plants here mainly on account of their manner of growth. Many of their characters bring them very closely indeed to *G. herbaceum.* The majority of the forms, ranging from Baluchistan westward to the Mediterranean, arranged under *G. herbaceum*, may really belong here, but I have seen only herbarium examples of these.

G. obtusifolium, *Roxb. var. nov.* Nanking. With most of the characters of the type, but leaves of a darker green resembling those of *G. neglectum. Bolls* and *bracteoles* comparatively large.

The types are *Wa-gale* and *Wa-gyi* of Burma with good cotton and two cottons from seed imported from China. This may be *G. Nanking,* Meyen. The Chinese plants have not grown well, but they seem closely allied to the two Burmese forms included with them.

G. obtusifolium, *Roxb. var. nov.* sindica. Branches more sparse and spreading than in type, upper with a strong tendency to become successively shorter. *Leaves* larger, of a bright yellowish green colour resembling those of *G. indicum.* This variety may be a connecting link between *G. obtusifolium* and *G. indicum.* The type is recorded from Sind only.

The extra-Indian distribution of *G. obtusifolium,* Roxb. includes the Philippines (*Vidal*), where it is wild, Timor, Letti and Lakor in the Malayan Archipelago, Nyassa Land, Central Africa, Transvaal, Madagascar, Hadramant (*T. Bent*), Zambesi, Somali Land and Rhodesia. Dr. Masters says in Fl. Brit. India, I, page 347, that this was the form found in Ava by Griffith, Journals, page 147. Many of the extra-Indian specimens quoted under *G. herbaceum* may more properly come here, but it is impossible to decide the matter from herbarium materials alone.

2. Gossypium arboreum, *Linn. Sp. Pl., p.* 693 (1753), *Todaro l.c. G. album,* Ham, *teste Herb. Wight,* 176 ; *Roxb. Fl. Ind., III,* 183. Perennial, reaching 7 feet in height. *Stems* robust, internodes short, all the branches acutely ascending. *Branches* dark red with close, very short stellate hairs mixed with longer, simple, pilose hairs, as are also the petioles and leaves. *Leaves* 5-lobed, lobes narrowly oblong or ovate-oblong sub-obtuse mucronate, sinus broad, often with small accessory basal or lateral lobes. *Inflorescence* in short secondary and tertiary divisions of lateral branchlets, drooping. *Bracteoles* ovately triangular acute, 1 inch by $\frac{7}{8}$ inch average length and breadth, quite entire or 1—3

toothed at apex or with teeth extending throughout two-thirds of the margins. *Corolla* about one-third longer than the bracteoles, dark red, fading almost to a black colour. *Calyx* loose, campanulate, limb truncate or with a few minute teeth, tube with three distinct glands at the base externally. *Bolls* brown, opening fully when ripe so that the cotton hangs down, as long as or a little longer than the bracteoles, ovate pointed, obtusely trigonous, $1\frac{1}{8}$ inch long by $\frac{7}{8}$ inch broad, cells usually 3. *Cotton* scanty, moderately fine and curly ; *seeds* 3 to 8 in each cell, *velvet* greenish grey.

The type has the lobes of the leaves narrow. Many examples have been received from Gujarāt, United Provinces, Madras, Central Provinces, Burma and Central India. Wherever found, it seems to be cultivated only on a very small scale. According to Hove, this red-flowered perennial cotton was cultivated largely in Gujarat.

G. arboreum, *Linn. var. nov.* platyloba. This only differs from the type in having the lobes of the leaves broad. Examples were obtained from Madras Presidency only. Mysore, *Heyne*, in Herb. Kew. Serampore, Bengal, *Griffith*, Herb. Kew.

G. arboreum, *Linn. var. nov.* vagans. This differs from the type in having drab-coloured cotton. The only examples are from Central India and Madras. A form of this variety may be partly *G. Nanking*, Meyen.

The extra-Indian distribution of *G. arboreum*, Linn., includes the type in Java (Horsfield) and Siam (Zimmermann). The *variety* platyloba is found in Japan (Oldham, Maximowicz), Pekin (Bushell, Index Floræ Sinensis under *G. herbaceum*, L.), Yunnan (Delavay), China (cultivated, A. *Henry*, No. 11,024), Formosa (cultivated, A. *Henry*, 1899), Shanghai (cultivated, Carles, 388), China (Fortune), Celebes (Riedel), Abeokuta (Irving), and Central Africa.

3. Gossypium sanguineum, *Hassk. Cat. Hort. Bog.* 200, (1844), *Todaro, l. c.*, G. rubicundum, *Roxb. Ic. Ined. et in Herb.* This differs from *G. arboreum* in being of more spreading growth, not so decidedly red in colour and in the foliage

being of a more glaucous hue. The typical form has dark red flowers.

(*a*) *Leaves* with broad lobes. Types—*Bagar siah*, *Bagar safed* and *Lyallpur Farm selected*, all from the Punjab.

(*b*) *Leaves* with narrow lobes. Types—Forms of *Bagar siah* and *Bagar safed* of the Punjab.

G. sanguineum, *Hassk. var. nov.* minor. As in type, but plants with pink flowers.

(*a*) *Leaves* with broad lobes. Forms of *Bagar siah*, *Bagar safed and Deshi Multan* of the Punjab.

(*b*) *Leaves* with narrow lobes. Forms of *Bagar siah* and *Bagar safed* of the Punjab.

The extra-Indian distribution of *G. sanguineum* is uncertain and probably coincides with that of *G. arboreum.*

4. Gossypium herbaceum, *Linn. Sp. Pl. I., p. 693* (1753) *Masters in Fl. Brit. Ind., I., p. 346* (excluding all the four varieties), *Todaro l. c.* Varying in height from 2 to 7 feet, basal branches long and spreading, median and upper also long and spreading, drooping in fruit; older parts greyish brown, slightly hairy, young parts green covered with black dots and soft, white spreading hairs: the sides of the branches facing southwards gradually turning to a dark red colour. *Stipules* ovate to linear lanceolate, falcate, about ½ inch long, the broader ones sometimes lobed towards apex. *Leaves* rather membranous, yellowish green, shallowly cordate rotundate, palmately 3—5 more lobed, lobes deep ovate obtuse or acute, margins quite entire or sinuate, sinus folded: basal lobes, when present, are above the sinus and do not rise from it. *Inflorescence* on short secondary or tertiary axes. *Bracteoles* spreading in fruit, rounded, with about 8—10 lanceolate acuminate teeth, reaching one-fourth of the way down. *Calyx* cup shaped, entire, accrescent and irregularly splitting, with three external basal glands. *Corolla* yellow with a black eye, fading to yellow suffused with red, ½ to ¾ inch longer than the bracteoles, *anthers* dark yellow with rather short filaments, *stigmas* short, channels straight or slightly twisted. *Capsule* 3-

or 4-celled, almost spherical or ovate, pointed, shorter than the spreading bracteoles. *Seeds* 5 to 8 in each cell.

Typical examples are *Lālio* of Kathiawar. *Kumpta* and *Jowāri Hatti* of the Southern Mahratta Country, *Broach, Gogāhri, Lālio* (Chhārodi) and *Kānvi*, all of Gujarat.

G. herbaceum, *Linn. var. nov* madraspatana. With smaller bolls but otherwise as in type, of which it is probably a degeneration. Typical examples include the *White-seeded Jowāri Hatti, Mungari* or *Billai, Uppam, Northerns* (Cuddapah), *Proddatur*, all of the Madras Presidency. *Manva* (Pratabgarh) is the solitary representative in the United Provinces. Mr. Benson says that 'Westerns' include *Jowāri Hatti* (white and black seeded). *Mungari* and *Bilé Hatti* and that these are found on the loams and clays. The trade term 'Northerns' includes the Northerns of this list and *Yerraputti* (*G. indicum*), the distribution being mainly according to soil as above. *Salems* include three different varieties, *viz.*, *Uppam, Nadam* or *Ladam*, and *Bourbon*. The *Uppam* resembles in every way, except that the lint is harsher, the *Uppam* of the districts further south and is the crop of clays and loams. The trade term 'Tinnies' includes the *Uppams* and "*Mundai kai* and *Karunganni*" or "*Manji kai*" varieties. These two sorts are habitually sown mixed, but the proportion of *Uppam* is larger in the north and of *Karunganni* in the south. It seems probable that the latter is the true Tinny Cotton, for *Uppam* is known in some places as *Udamalpet* cotton, Udamalpet being a town in the 'Salems' area. *Mungari* is a special sort which appears to differ from the ordinary *Jowāri* (not *Jowāri Hatti*) in respect of the time of sowing. *Karunganni* belongs to *G. obtusifolium*, Roxb.

G. herbaceum, *Linn. var. nov.* melanosperma. As in the last, but testa of seed naked. There is only one typical example from the Madras Presidency, said by Mr. Benson to be included in 'Westerns.'

G. herbaceum, *Linn. var. nov.* sakalia. *Bolls* spherical, with broad valves splitting so slightly when ripe that the cotton does not emerge, mostly 3-celled, averaging one inch in length and

breadth. The typical examples are two only; *Wāgad* and *Sakālio* of Gujarat.

I am altogether in doubt as to the extra-Indian distribution of G. herbaceum, *Linn.*, having never seen living examples of the cottons ranging from the western frontiers of India to Eastern Europe and included under this name. Specimens from the following countries seem to belong to this species, but they may just as well be considered forms of *G. obtusifolium*, Roxb.: Turkey, Greece, Armenia, Persia, Cephalonia, Crete, Khorasan (*Aitchison*), Afghanistan, Gilgit (*Giles* and also *Winterbottom*).

5. GOSSYPIUM INTERMEDIUM, *Todaro, Osser sui Cotoni, p. 41 (1863)*; G. intermedium, *Tod. var.* Royleanum, *Tod. l.c.* = ? broad-lobed type; G. neglectum, *Tod. var.* Roxburghianum, *Tod. l.c.* = ? G. herbaceum *var.* Dacca Cotton, *Roxb. Fl. Ind. III, 184*, teste *Tod. l.c.* = ? *Jethia* of Bengal. Attaining 5 to 6 and more feet in height, *branches* ascending more sharply than in *G. herbaceum*, reddish. *Leaves* dark green, sub-coriaceous, glabrescent, palmately 5—7-lobed, lobes ovate acute, sinus broad with a fold or rarely with an extra-basal lobe. *Bracteoles* not spreading, subtriangular, ovate, gashed more or less on the whole margin. *Bolls* small $\frac{7}{8}$ by $\frac{5}{8}$ inch, round and pointed. *Cotton* scanty, short, moderately fine; *seeds* 3 to 8 in each cell, velvet greenish white. The following forms are transitional between the Burmese and Chinese types of *G. neglectum* and *G. herbaceum*.

(*a*) Lobes of leaves broad. *Dēshila* or *Dēshi* and *Jēthi* of Bengal, *Bāgil* of Gorakhpur, U. P.

(*b*) Lobes of leaves narrow, *Sūltānpur; Rādhiya kapās; Mānva* of the United Provinces.

G. intermedium, *Tod. var. nov.* alba. *Flowers* white. *Bracteoles* often entire. A form nearer *G. neglectum* than *G. herbaceum*. Type from United Provinces only. Mr. Moreland (Director of Agriculture, United Provinces) says that these cottons are cultivated on a small scale only on the eastern side of the Upper Provinces.

The extra-Indian distribution of *G. intermedium*, Tod., is unknown. The plant is probably endemic. There are no specimens at Kew.

6. GOSSYPIUM INDICUM, *Lamk. Dict. Encycl. 2, p. 134* (1786): G. Wightianum, *Tod. Osser sui Cotoni, p. 41* (in part). *Stems* up to 8 feet in height, simple, tapering gradually from base to apex; basal branches long, ascending, medial moderately long, uppermost small. *Leaves* varying from entire to usually 3- or occasionally 5-lobed, base cordate, lobes broadly ovate, sinuses broad. *Bracteoles* ovate-pointed, entire or few toothed at apex. *Bolls* ovate acuminate, 3- 4-celled; *cotton* scanty, staple silky, long; *seeds* in each cell 4—10, covered with grey brown velvet. Typical plants have yellow flowers. Bengal and Madras have each one form; the United Provinces have two; the remainder come from Central India, the Punjab and the Central Provinces.

Of *Yerraputti* Mr. Benson says that it seems, like *Karunganni*, to partake more of the *G. indicum* than of the *G. neglectum* type, but possibly it includes more than one variety. Plants so named are found widely as scattered plants in greater or less proportion over the areas where both Northerns and Westerns are produced. Properly speaking, this variety is not one to be grown on "Cotton soils."

As regards the Central Provinces, Mr. Standen (Director of Agriculture) says that *Bani* is a more delicate and later ripening variety with longer and silky staple. It used to be grown largely in the Wardha district as well as in the neighbouring parts of Berar, but is being thrust out by the *Jari* (G. neglectum), because the latter even in the most favourable years pays better than *Bani* in all but the most suitable localities. The Assistant Director of Agriculture believes that *Nimari* is *Bani*, of which the character has been somewhat altered by transfer to a drier climate. The *Chandā Jari* is a cold weather variety yielding a smaller outturn than *Jari* or *Bani*, but producing cotton of better quality than either. From Mr. Shevade's report on the cotton of Barsi in the Sholapur District, it would appear that *Bani* once formed the bulk of the so-called Barsi cotton.

Gossypium indicum, *Lamk. var. nov.* Mollisoni differs from the type only in having white flowers. The examples are all

from Central India and the Punjab, with the exception of one from the Central Provinces and two from the United Provinces.

The species seem to be endemic to India.

7. Gossypium neglectum, *Todaro, Osser sui cotoni, p. 35* (*1863*). . G. herbaceum, *Linn var.* hirsutum, *Masters* in Herb. Kew. G. arboreum, *Linn.* (in part) *Fl. Br. Ind., I, 347.* Plants varying in height from 3 to 7 and more feet. *Stems* simple, wandlike, tapering gradually from base to apex, bark brown, tessellated, quite glabrous below, with simple, white short deciduous hairs above, herbaceous parts brownish red, specially so on the southern side. Lower branches sparse, long, spreading, medial short, uppermost very short; whole plant usually nodding if well covered with fruit *Leaves* palmate or palmatipartite, lobes 3 to 5 or more, oblong lanceolate, ovate acute or sub-obtuse, sinuses broad or rising up into small extra lobes, base shallowly cordate; *glands* either altogether absent or present on the central rib or faintly present on the three central ribs; *stipules* lanceolate falcate acuminate or broad ovate few toothed at the apex. *Flowers* one from each node of the lateral branches, *peduncles* erect but drooping in fruit. *Bracteoles* deeply cordate, ovate acute, quite entire towards apex or sometimes toothed there. *Calyx* cup-shaped, entire or very shortly lobed. *Corolla* a little longer than the bracteoles, upper part of petals reflexed; *filaments* comparatively long; *stigmas* 3-grooved, scarcely rising above the upper anthers, channels with or without black dots. *Bolls* ovate, obtusely pointed, invested at base by the ruptured enlarged calyx, 3—4-celled, very distinctly black dotted, valves separating and recurved when ripe. *Cotton* harsh, clinging more or less firmly to the seed, which is covered by grey velvet.

G. neglectum, *Tod. l.c. var. nov.* vera. Lobes of leaves narrowly oblong, base not deeply cordate. *Flowers* yellow. *Cotton* copious and coarse. This variety is represented by forms from the Punjab, United Provinces and Central India. The latter area seems to have been the place of origin of both this species and *G. indicum.*

G. neglectum, *Tod. var. nov.* vera., *sub. var. nov.* malvensis. Similar to the last but lobes of leaves usually broader and the

cotton of superior quality. This form is a connecting link with *G. indicum.* Examples are from Sind, Punjab, Central India and the United Provinces.

G. neglectum, *Tod. var. nov.* vera, *sub. var. nov.* kathiavarensis. Lobes of leaves broad ovate oblong. *Cotton* moderately fine. It is represented by two varieties from Kathiawar, *Hirvāni* and *Mathio* and doubtfully by a variety called *Barkley*, Ralli Brothers, in the Central Provinces.

G. neglectum, *Tod. var. nov.* vera, *sub. var. nov.* bengalensis. Lobes of leaves narrow, radiating. *Bolls* and *bracteoles* larger than in type. *Cotton* coarse. It is represented by several examples in Bengal, three in Assam and one in the United Provinces. It is closely allied to *G. cernuum.*

G. neglectum, *Tod. var. nov.* vera, *sub. var. nov.* burmanica. As in bengalensis, but lobes of leaves broad, *cotton* white. It is represented by a series of similar forms from Burma and by three varieties from Assam. The Director of Agriculture states that *Lassing Anguangba* or *Tissing Anguangba* is grown in Manipur.

G. neglectum, *Tod. var. nov.* vera, *sub. var. nov.* Kokatia. Characters as in the last, but *cotton* drab coloured. One example from Bengal, two from Assam and a short series from Burma. This may be one of the forms included by authors under *G. Nanking*, Meyen.

G. neglectum, *Tod. var. nov.* rosea. G. roseum, *Tod. Osser sui Cotoni*, p. 22. This is separated from G. neglectum, *var.* vera, only by the white flowers. There are examples from the Central Provinces, Punjab, United Provinces, Bengal and Sind.

G. neglectum, *Tod. var. nov.* rosea, *sub. var. nov.* cutchica. Lobes of leaves broad, ovate oblong ; *cotton* moderately fine. Represented by three white-flowered cottons of Kathiawar, *Hirvāni*, *Mathio* and *Mōtō mathio.*

G. neglectum, *Tod. var. nov.* rosea, *sub. var. nov.* avensis. Lobes of leaves broad. *Bracteoles* and *bolls* larger than in type. Represented by two Burmese cottons and one doubtful plant from the United Provinces.

The extra-Indian distribution of *G. neglectum, Tod.*, is unknown.

8. Gossypium cernuum, *Tod. Osser sui Cotoni*, p. 31. General characters as in *G. neglectum. Leaves* usually with very narrow radiating lobes. *Bracteoles* ovate acute, quite entire towards apex or with 3 to 6 acuminate teeth; dimensions in flower 1 to 2 inches long, $\frac{3}{4}$ to $1\frac{1}{4}$ inch broad. *Corolla* about $\frac{3}{4}$ inch longer than the bracteoles, white or pale yellow, with a dark eye, dying pink. *Bracteoles* in fruit up to $2\frac{1}{2}$ inches long, slightly shorter or longer than the bolls which are ovate pointed, 3—4 celled, very distinctly black dotted. It is represented by a series of forms in Assam, by an introduced variety in Sind and by another variety, perhaps also introduced, in the United Provinces. The Director of Agriculture, Assam, states that the *kil* is grown in the Garo Hills and probably also on the northern slopes of the Khasia Hills. Its pods are very large, being sometimes as much as eight inches in length. The quality of the lint is harsh and only fit for mixing with wool. *Bor Kapah* and *Soru Kapah* are grown in the Mikir Hills and in the adjacent plains country in Nowgong and Golaghat by the hill tribes (mostly Mikirs). They are also grown to a very small extent in some plain's mauzas of Kamrup.

G. cernuum, *Tod. var. nov.* silhetensis. Differs from the type only in having drab-coloured cotton. It is represented by four examples from Assam, one introduced into Sind and one Chinese. The last may be one of the forms known as *G. Nanking*, Meyen.

The extra-Indian distribution of *G. cernuum, Tod.*, is doubtful, but it is probably endemic in North-Eastern India and China.

9. Gossypium hirsutum, *Mill. n.* 4 (1759) = G. jamaicense, *Macf. Fl. of Jamaica*, p. 72 = ? G. punctatum, *Thon. and Sch.* Guin Pl. p. 2, p. 84. Upland Georgian cotton, *Royle, Cotton Cultivation, tab.* 3, *fig.* 4. Upland Georgian cotton; Short Staple cotton; Bourbon cotton; Louisiana cotton (*Parlatore*). From 2 to 4 feet high. Lower branches erect, upper spreading

so that a well-grown plant forms a round-headed bush; older parts of the stems and branches smooth, grey; younger parts green, gradually turning brown, covered with moderately stiff spreading white hairs and minute black dots; *stipules* lanceolate, falcate, about ½ inch long. *Leaves* sub-coriaceous, dark green, drying red, varying much in shape, ovate or ovate cordate entire, cordate with I to 3 shallow lobes or palmately cordate with 3 shallow or very deep triangular or ovately triangular acute lobes which point forwards, base of blade with a red blotch. *Bracteoles* rounded, upper half of the margins with about ten falcately lanceolate acuminate teeth, the central ones exceeding the corolla in length, in bud and fruit clasping over like the fingers of two hands. *Calyx* campanulate, accrescent but not usually splitting in fruit, with 5 distinct triangular lobes. *Corolla* pale yellow without an eye, fading red. *Anthers* with rather long filaments so that they droop. *Stigmas* long, consolidated, twisted. *Bolls* usually 3- , sometimes 4-celled, spherical ovate obtuse shortly mucronate with the persistent base of the style a little longer than the bracteoles. *Cotton* silky, long in the staple. *Seeds* densely covered with grey velvet, 6—9 in each cell.

This species is only included amongst the Indian cottons, as it has become quite naturalized in some parts of India, especially in the Karnatak. There are examples from Dharwar, Nagpur. Central Provinces, Assam, Bengal, United Provinces and Punjab.

G. hirsutum, *Mill. var.* rufa, *Todaro.* Only differs from the type in the cotton being drab coloured. Synonymy according to Parlatore is, G. siamense lana rufa, *Ten. l. c.* G. religiosum, *Moris. Fl. sard. I*, p. 309. Coton de Siam, Cotone Isabelle of the French, Cotone siamese, Cotone maltese, Cotone Rosso, Cotone color di legno. We have examples from the Punjab, United Provinces and Central India.

As regards the extra-Indian distribution of G. hirsutum, *Mill.*, Parlatore gives Mexico and Galapagos as the habitat. It is cultivated in Central and North America, Canary Islands, Cape Verde, Western Coast of Tropical Africa, Algeria, Egypt, Abyssinia, Isle of France, Bourbon, Southern Italy, Sicily,

Sardinia, Malta, Crete, Indo-China, Amboyna, Queensland, New South Wales and New Holland. I have personally examined specimens from the following localities: Angola, St. Jago, San Domingo, Lagos, (wild cotton of Radajry District), Zambesi, Egypt, Alabama, Florida (under G. uliginosum, *Linn.*), Costa Rica, Mexico, Florida (under G. racemosum, *Poir.*).

DESCRIPTIONS OF THE PLATES.

PLATE I.—G obtusifolium, *Roxb.*; A. *Nadam of Madras*, B. *var.* Coconada, open boll. C. seed without cotton.

PLATE II.—G. obtusifolium, *var.* hirsutior; A. part of plant; B. open flower; C. half ripe boll; D. ripe boll; E. seed with cotton; F. seed without cotton; G. bracteole.

PLATE III.—G. obtusifolium, *var.* Nanking; A. part of plant; B. open flower; C. half ripe boll; D. ripe boll; E. seed with cotton; F. seed without cotton; G. bracteole.

PLATE IV.—G. obtusifolium, *var.* sindica; A. part of plant; B. open flower; C. two types of bolls; D. bracteole.

PLATE V.—G. arboreum. *Linn*; A. part of typical plant; B. leaf of *var.* platyloba; C. ripe boll and cotton of *var.* vagans; D. ripe boll and cotton of type; E. seed with cotton of type; F. seed without cotton of type; G. bracteole.

PLATE VI.—G. sanguineum, *Hassk*; A. part of plant of *var.* minor; B. petal of same; C. a broad-lobed leaf; D. flower of type; E. bracteole of type; F. seed with cotton; G. seed without cotton; H. unripe boll of *var.* minor; I. ripe boll of *var.* minor; J. ripe boll of type.

PLATE VII.—G. herbaceum, *Linn.* A. part of plant of type; B. boll of *var.* madraspatana; C. seed with and without cotton of *var.* melanosperma; D. ripe boll of *var.* sakalia; E. half ripe boll of type; F. open flower of type; G. ripe boll of type; H. seed with and without cotton of type.

PLATE VIII.—G. intermedium, *Tod.*; A. part of plant of type; B. part of plant of *var.* alba; C. D. bracteoles of *var.* alba; E. half ripe boll of *var.* alba; F. ripe boll of same; G. seed with and without cotton of type.

PLATE IX.—G. indicum, *Lamk.*, and G. neglectum, *Tod. var.*; A. part of plant of type; B. flower of *var.* Mollisoni; C. half ripe boll of type; D. ripe boll of type (marked G. in left hand lower corner); E. seed with and without cotton of type; F. ripe boll of *Lassing Anguangba*; G. seed with and without cotton (transferred to G. neglectum, *var.* vera. *sub-var.* Kokatia).

PLATE X.—G. neglectum, *Tod. vars.* vera. and rosea; A. part of plant of G. neglectum, *var.* rosea; B. flower of *var.* vera.; C. leaf of *var.* vera. *sub. var.* malvensis; D. bracteole of *var.* rosea; E. ripe boll of the same; F. seed with and without cotton of the same.

PLATE XI.—G. neglectum, *Tod. sub. vars.* cutchica and kathiavarensis; A. part of plant of *var.* rosea, *sub. var.* cutchica; B. flower of *var.* vera. *sub. var.* kathiavarensis; C. bracteole of *sub. var.* cutchica; D. ripe boll of same; E. seed with and without cotton of same.

PLATE XII.—G. neglectum, *Tod. sub. vars.* burmanica and Kokatia; A. part of plant of *var.* vera, *sub. var.* burmanica; B. flower of same; C. bracteole of same; D. half ripe boll of same; E. ripe boll of same; F. seed with and without cotton of same; G. ripe boll of *sub. var.* Kokatia.

PLATE XIII.—G. cernuum, *Tod.*, G. neglectum, *var.* vera, *sub. var.* bengalensis; A. part of plant of type; B. bracteole of type; C. half ripe boll of type; D. ripe boll of same; E. ripe boll of *var.* silhetensis; F. flower of G. neglectum, *var.* vera., *sub. var.* bengalensis; G. half ripe boll of same.

PLATE XIV.—G. hirsutum, *Mill.* A. part of plant of type; B. flower of same; C. bracteole of same; D. half ripe boll of same; E. ripe boll of same; F. seed with and without cotton; G. ripe boll of *var.* rufa.

R. K. Bhide, del. Huth, Lith^r London.

G. OBTUSIFOLIUM Roxb

R.K. Bhide del

G. OBTUSIFOLIUM var HIRSUTIOR.

Huth, Lith^r London.

R. K. Bhide, del. Huth, Lith^r London

G. OBTUSIFOLIUM Roxb. Var. NANKING.

G. OBTUSIFOLIUM ROXB. VAR. SINDICA.

R. K. Bhide, del. Huth, Lith^r. London

G. ARBOREUM, Linn.

R K Bhide. del. Huth, Lith. London

G. SANGUINEUM. Hassk.

Plate VII

del. G HERBACEUM Linn Huth

R. K. Bhide, del. Huth, Lith^{r} London.

G. INTERMEDIUM Tod.

Huth Lith[t] London

G. INDICUM. Lamk and G. NEGLECTUM. Tod. var

R K Bhide, del G. NEGLECTUM. Tod. vars. VERA and ROSEA. Huth, Lith^r London

G. NEGLECTUM. Tod.
sub. vars CUTCHICA and KATHIAWARENSIS.

R. K. Bhide, del.

Huth Lith^r London

G. NEGLECTUM. Tod
sub. vars BURMANICA and KOKATIA

R.K. Bhide del. Huth Lith[r] London

G. CERNUUM. Tod.
G. NEGLECTUM. var VERA sub.var. BENGALENSIS.

R K Bhide. del.

Huth, Lith[r] London.

G. HIRSUTUM Mill.

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA.

NOTE ON A TOXIC SUBSTANCE EXCRETED BY THE ROOTS OF PLANTS.

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NOTE ON A TOXIC SUBSTANCE EXCRETED BY THE ROOTS OF PLANTS.

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It has more than once been suggested that plants, like animals, excrete (from their roots) material that is no longer of use to them or that are bye-products of the process of metabolism, and that such substances are injurious to the kinds of vegetation by which they are excreted. Brugmans was apparently the first to suggest this, and it has, at various times, been affirmed by Plenk, Humboldt, Cotta, De Candolle and others, denied by Hedwig, Braconnot, Walser, Boussingault, Unger, Meyen and others and has for long been considered as non-existent except with regard to carbon dioxide and possibly an acid phosphate and formates.

Again, Dr. Gyde (Trans-Highland and Agricultural Society, 1845-47, pp. 273-92) in water cultures obtained on evaporating the residual liquid, a very small amount of yellowish or brown substance, a portion of which was organic in character. He concluded that the amount excreted was very small, and that the substance was not injurious to the plants that gave rise to it.

From observations on crops growing in the field, the writer some years ago (while in Egypt) came to the conclusion that certain phenomena could only be explained on the theory of excretion. This was especially the case with cotton crops in which a grass was allowed to grow as a weed. The cotton, grown under irrigation, did not revive on application of more water; its poor state was therefore not due to lack of moisture in the soil. Manures likewise seemed to have comparatively little effect towards improvement; appropriation by the weed of food materials was therefore not the cause of the poor growth. Aeration had as little effect as manure.

Observations in the field were resumed in India, and these tended to very materially strengthen the view that materials injurious to other crops were excreted by the roots of certain common crops in India; this was especially the case with sorghum. The system of mixed crops very prevalent in the unirrigated tracts in India gave full opportunity for a number of observations to be taken, and on the strength of these, experiment was resumed both in the field and in water culture.

Field Experiments.

The results of field experiments which commenced (in India) in the season 1903-04 were unreliable in the two following years owing to the failure of the monsoon. In the season of 1906-07, the rains were more nearly normal, and the following observations were made on the Surat Experiment Station; they agree in kind and differ only in degree from those obtained in the previous year under a short rainfall.

This Station is on typical deep black cotton soil and receives an annual rainfall of about 42 inches, all falling between the middle of June and the end of September.

The soil is very retentive of moisture as will be obvious from the fact that cotton sown in June survives until the end of March, though no rain is received during the last six months previous to the final picking of the crop. The composition of this soil, as kindly analysed by Dr. Leather, is as follows :—

Mechanical Composition.

Fine Gravel, 1 mm.	...	2·2
Sand,	1 mm. –0·2 ...	3·4
,,	0·2—0·05 mm. ...	42·2
,,	0·05—·01 mm. ...	22·8
,,	·01 mm. ...	20 8
		91·4
Stones	...	3·6
Fine earth, 2 mm.	...	96·4
		100·0

CHEMICAL COMPOSITION.

Insoluble silicates and sand	68·06
Ferric oxide	8·83
Alumina	11·07
Lime	2·79
Magnesia	·54
Potash	·42
Soda	·31
Phosphoric acid	·09
Sulphuric acid	·06
Carbonic acid	·94
Chlorine	·07
Organic matter and combined water	6·82
	100·00
Total nitrogen	·036
Nitric nitrogen	·00014
Available phosphoric acid	·016
Available potash	·012

The observations were taken as follows :—

Plots of various crops were grown side by side, each plot being sown by means of a drill in such a way that the rows of crops (2 ft. apart) were parallel in all the plots. Further, several plots were left fallow as it was found that some crops growing on the border of a fallow yielded at a rate as much as 10 times as great as the rate in the centre of the plot (Annual Report of the Bombay Farms for 1904-05). Again, cotton and sorghum were sown in alternate rows in the same plot.

The following observations were then made :—

(1) The yield of the row of each crop bordering on fallow.

(2) The yield of the row of each crop bordering on a plot bearing another crop.

(3) The yield of a row of each crop in the centre of a plot bearing only that crop.

(4) The yield of a row of cotton when grown with a row of sorghum of each side (at a distance of 2 ft.).

(5) The yield of the row of sorghum when grown with a row of cotton on each side (at a distance of 2 ft.).

In all cases the results given are the mean of a large number of observations.

Observation (1) is the nearest approach possible under the conditions of the experiment, to the yield of a crop when grown isolated, *i.e.*, influenced neither by plants of the same nor of other species. In the present season it is hoped to obtain a nearer approximation.

The results obtained (1906-07) are given in the table following, the total yield per acre (dry weight) of the crops being given in lbs. :—

TABLE I.

CROPS (*of which yield is given.*)	YIELD (fruit and vegetative portion) in lbs. per acre of the crops in first column when grown bordering on a plot of :				
	Fallow.	Sorghum.	Cajanus.	Cotton.	Sesamum.
Sorghum	10,735	4,830	8,051	8,802	8,158
Cajanus	4,633	694	1,621	1,621	2,409
Cotton	3,817	229	763	1,145	1,259
Sesamum	1,650	*Nil*	198	247	643

Taking the yield next to the fallow as a rough approximation to the yield of the isolated crop, we get the following percentage reduction in these yields produced by a neighbouring plot* of another crop :

TABLE II.

CROPS (*of which percentage decrease is given*).	Percentage DECREASE in yields of crops in first column when grown near			
	Sorghum.	Cajanus.	Cotton.	Sesamum.
Sorghum	55	25	18	24†
Cajanus	85	65	65	48
Cotton	94	80	70	67
Sesamum	100	88	85	61‡

* In the present season observations will be made on the yield of crops when a row is bordered on *both* sides by another crop.

† Since sesamum is extremely sensitive to the presence in its vicinity of other plants whether of the same or other species, the yield next to fallow (Table II) is probably lower than the *isolated* yield by a much greater extent than in the case of all other crops, since the latter are less sensitive. The figures in the bottom line of Table II should therefore all be increased.

‡ This is the result of one observation only and is probably too high since sesamum will not grow at all within 2ft. (the width of the rows) of sorghum.

It is to be noted that pending further and more precise experiment the figures in Table II are to be considered as indicating only the order of the influence of various plants on one another and that too only under the particular conditions of soil and climate under which the experiment was conducted. On lighter soils and under a more evenly distributed rainfall the percentage reductions are apparently less. With this reservation and since the decreased yields are not restored by either irrigation, manure, aeration or light,* it appears legitimate to draw the following conclusions :—

(1) All plants excrete substances which are toxic both to themselves and to other species.

(2) The quantity of material excreted by the different crops varies when reckoned per unit area of a field sown in the ordinary way.

(3) The sensitiveness of crops to the same quantity of the excreted substance varies with the variety of the crop.

(4) The substance excreted by all crops is apparently identical.

The last statement is made under a further reservation pending the isolation in a pure state and analysis of the excreted substance or substances. There is, however, nothing in the facts so far observed either in the field or in water culture inconsistent with the identity of the substance excreted by all plants. On the other hand, if the substance excreted varied with the species, we should not expect the regularity found in Table II. Thus, reading that table vertically, the order of sensitiveness to a given amount of the substance excreted by sorghum appears to be (beginning with the least sensitive) :—sorghum, cajanus, cotton, sesamum. The same order holds good for the same plants towards the substance excreted by cajanus, by cotton and by sesamum. If now the excrement from sorghum differed not only in quantity but also in kind from that of cajanus, we should

* All these factors have been proved by experiment to be incapable of correcting except very partially the poorer growth except in the case of certain manurial substances (*see* later).

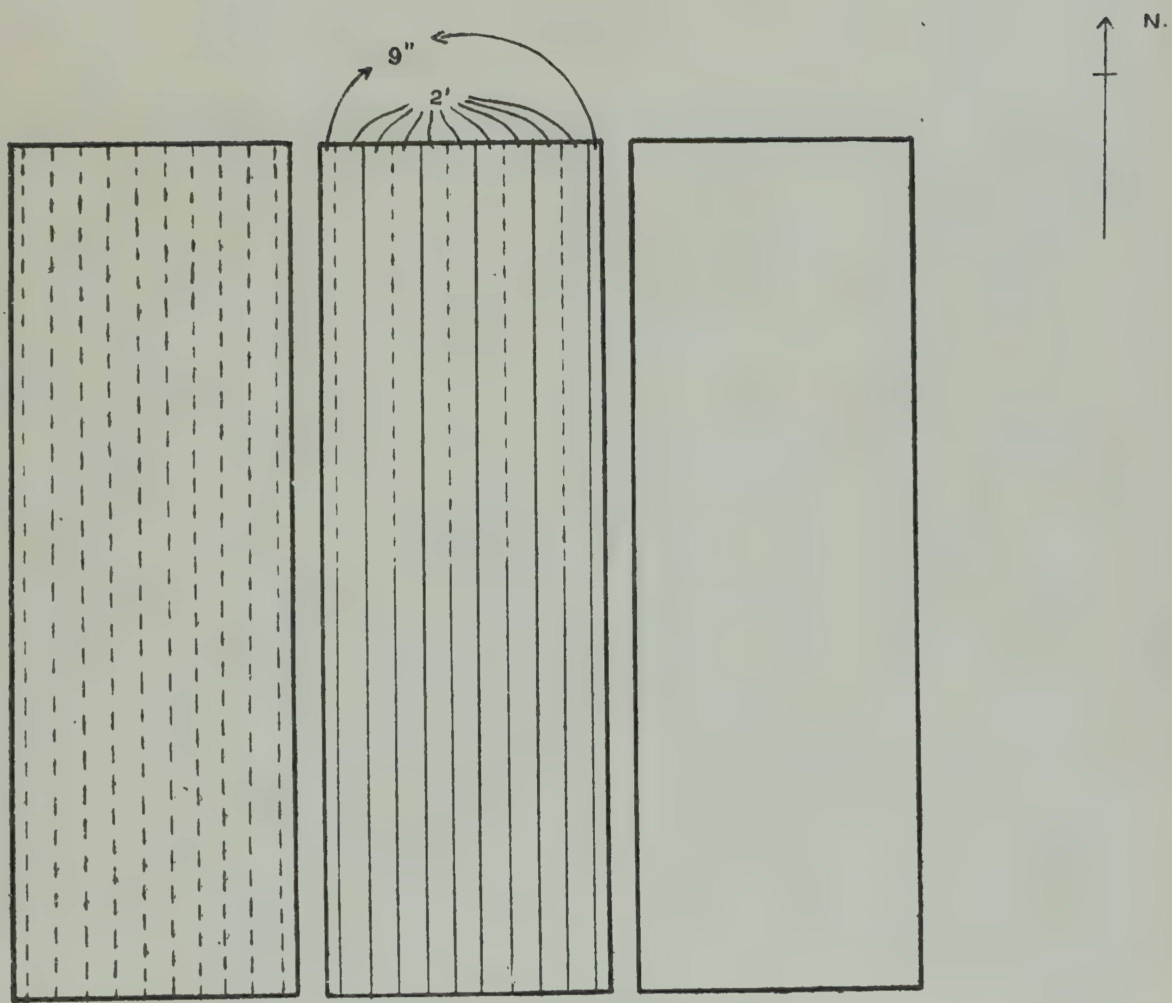
expect that if in two species of plants one was the more resistant to a given quantity of sorghum excrement, yet the other might be the more resistant to the excrement from, say, cajanus. This has, however, been observed to be the case neither in the field nor in water cultures.

Further, the amount of substance excreted (per unit area of a field sown under the conditions of the experiment) by the various crops *appears* to be in the same order. For, reading the columns of Table II horizontally, we find that sorghum excretes an amount of substance which reduces its own yield by 55 per cent., while cajanus excretes an amount that reduces the yield of sorghum by 25 per cent., cotton an amount that reduces the yield of sorghum by 18 per cent. The regularity of the table as read thus horizontally may, however, be deceptive.

On the Dharwar Experimental Station a few observations (on other crops) were made, which indicate that gram (cicer) is about equally sensitive and equally toxic with wheat, that both are equally sensitive with sesamum but less toxic than the latter, while linseed is similar to cotton in both respects except perhaps that it is more sensitive.

In the experiment where cotton and sorghum were grown in alternate rows (2 feet apart) the following results given below in Table III were obtained. The figures are so remarkable that they are given in full. The experiment was made on $\frac{1}{4}$-acre plots, each 191 yards long and $6\frac{1}{2}$ yards wide, of which the record is known since 1897-98, when my predecessor, Mr. Mollison, laid them out for an excellent series of rotation and manure experiments. In numbering the rows, the numbers of the rows go in the same direction as the numbers of the plots themselves, so that the first row of a plot borders on the plot whose number is next lower and at a distance of $3\frac{1}{2}$ feet from it. The relative positions of the different crops will be obvious from the accompanying plan of one of the plots in which dotted lines represent rows of cotton; continuous thin lines, rows of sorghum; and continuous thick lines, the border of the plot.

PLATE I.



Plan showing relative positions of different crops at Dharwar Experimental Station.

The treatment of the plots whose northern halves were thus sown with alternate rows of cotton and sorghum had been since 1897-98 (except 1905-06) as follows :—

TABLE III.

Number of plot.	Treatment.
1 & 2 ...	Sown in alternate years with cotton and sorghum, 5 tons of farm-yard manure being applied before every cotton crop.
11 ...	In a three-year rotation Crotalaria ploughed in as green manure (followed in the same year by sesamum and cajanus) preceded cotton and this sorghum, each cotton crop receiving 5 tons of farm yard manure.
14 ...	Similar to plot 11, but the green manure was not followed by a crop in the same year.
24 & 25 ...	Sown in alternate years with cotton and sorghum, no manure being given.

In the season 1906-07 all the plots in the original series were sown with cotton, and all those in the duplicate series with sorghum except in both series the northern halves of plots 1, 2, 11, 14, 24, 25 (which were sown as indicated above) and plots 12 and 15 which were left fallow. The average yield (in lbs.) per acre (total produce) of the separate half rows is given in the following table :—

TABLE IV.

Number of plot.	SERIES I.			SERIES II. (DUPLICATE OF SERIES I).		
	SOUTHERN HALF.	NORTHERN HALF.		SOUTHERN HALF.	NORTHERN HALF.	
	Cotton.	Cotton.	Sorghum.	Sorghum.	Cotton.	Sorghum.
1	1,260	543	6,342	3,392	144	9,078
2	1,464	499	6,017	3,397	99	9,811
11	3,332	2,286	11,103	6,220	1,749	2,297
14	3,187	2,595	11,760	6,091	1,572	8,550
24*	896	385	3,550	2,752	154	6,089
25*	776	278	3,960	2,791	69	5,897

* Reckoned on ⅘ths of the plot only that was beyond the influence of a neighbouring fallow area.

At first sight the extraordinary difference between the yields (northern halves only) of series I and its duplicate series II would seem to indicate that the soil differed in the two

cases. The whole difference is, however, due to last year's cropping, series I being then under sorghum and series II under cotton except plots 11 and 14 which were fallow in both series. This accounts for the great difference in the yields of the northern halves of plots 1 and 2, 24 and 25, sorghum yielding much better after cotton (series II) than after sorghum (series I). The converse might appear to be the case with cotton which in series II (after cotton) has yielded less than in series I (after sorghum), and the whole might appear to be an example of the benefit of rotation. The small yield of cotton in series II is, however, due in part at least to the more vigorous growth of the sorghum with which it was sown as a mixed crop and only to a small extent to the fact that the preceding crop was cotton.

Water Cultures.

A large number of experiments in water culture were started some years ago. It is unnecessary to give the preliminary investigations on this point. The greater part of the results obtained by me have been brought together for a final test during the last few months, and these only will be here recorded.

Preparation of Solution of Excreta.

In December last, final water cultures were started on the Dharwar Experimental Station in a number (in all 20) of earthenware dishes (12 inches in diameter and 4 inches inside depth). In each of these dishes 4 litres of well water was placed, and over this a circular teak board perforated by 90 holes, $\frac{1}{4}$ inch in diameter, was supported by strings, to which were attached counterpoise weights hanging over the outside of the dish. Seeds were germinated in crushed quartz, and when the radicle was about an inch long, were transferred to the water culture dishes; a radicle was passed through each hole in the board and held in place by a small wad of cotton. In each 4 litres of water therefore 90 seedlings were planted; those that failed were replaced by others.

The crops were harvested, roots and all, every 21 days, and in all, three crops were taken from each dish between the 10th of January 1907 and May 15th. The water in the dishes was kept up to 4 litres by adding well water every few days.

The crops grown were cotton, sorghum, cajanus indicus, sesamum, wheat, gram (Cicer arietinum).

The air dry weights (including the roots) of the three harvests of the several crops is given in Table V.

TABLE V.

Air dry weights of crops and the amount of water into which the excreta had passed.

No.	Name of crop.	No. of plants grown.	Air dry weight in grammes.	Volume of well water in which their excreta was finally contained.	Total volume of water evaporated and replaced.
				Litres.	*Litres.*
1	Cotton	246	9·170	2·3	19·00
2	Sorghum ...	224	6·026	2·3	18·25
3	Cajanus	157	6·407	2·3	19·25
4	Sesamum ...	133	0·746	1·2	18·75
5	Wheat	261	7·766	1·2	19·75
6	Gram	261	19·308	1·2	27·75

The volume of water remaining in the dishes on harvesting the third crop was allowed to stand in a room until its volume was reduced to the quantity stated, this quantity having been indicated in previous tests to be the best for the final test.

Water culture in the excretory solution.

For brevity the various solutions obtained will be called 'cotton water,' 'sorghum water,' etc.

The water cultures were made in wide-mouthed bottles holding 100 c. c. when filled up to the neck. The mouth was plugged with a teakwood stopper in which four holes ($\frac{1}{4}$ inch diameter) were bored. Through these holes the radicle or the plumule of seedlings germinated in crushed quartz was passed, the seedlings being supported in place by a small wad of cotton.

In the case of cotton, cajanus and sesamum, the root was passed downwards through the stopper; in the other cases the

plumule was passed upwards. In the latter cases the plant was adjusted so that the seed was in position just above the surface of the water in the bottle.

The seedlings were very carefully chosen from several hundreds grown in crushed quartz, so as to be as nearly equal among themselves as possible. The state at which the seedlings are best suited to the purpose in hand was found by repeated experiment to be as follows :—

(1) *Cotton* when the spread of the cotyledons is $1\frac{1}{2}$ inches.

(2) *Sorghum* when the first and second leaves are equal (both about 1 inch long).

(3) *Cajanus* when the 'spread' of the first leaves is 4 inches.

(4) *Sesamum* as soon as the cotyledons have assumed a horizontal position.

(5) *Wheat* as for sorghum.

(6) *Gram* when the first three leaves have expanded.

The strength of the solutions had been so arranged (by allowing to evaporate) that no plant (of the size indicated) would grow in any of them for more than about ten days. The time between transplanting into the bottles and the times of commencement of wilting and of complete drying up were carefully recorded. The bottles were also weighed every morning and in some cases several times a day to find the amount of transpiration, this amount having been proved (Bulletin No. 28, Bureau of Soils, U. S. A.) to be a measure of the increase of the plant in dry weight.

In all cases two, and in some cases as many as six bottles were treated in the same way, both as regards the solution they contained and the crops grown in them. It was found that with careful selection of seedlings of each size the difference between duplicates either in time of withering or in loss by transpiration was extremely small. The observations here recorded are in all cases the mean of the total number of bottles sown in the particular manner indicated. They are set forth in the following tabular statement :—

TABLE I.

Progress of crops named in Column 1 when grown in water containing matter excreted by crops in Columns 2 to 7 and in distilled water.

CROPS (*of which progress is indicated*).		Crops that had previously grown in the water.						Distilled water.	
		Sorghum.	Cajanus.	Cotton.	Sesamum.	Wheat.	Gram.	Period of growth.	Weight in grams of transpiration.
1		2	3	4	5	6	7	8	9
Sorghum ...	Period (in days) after which withering commenced ...	1	1	1	1	1	1	6	4·7
	Transpiration (in grams) in that time	0	0	0	0	0	0		
	Total period of growth (in days)	5	3	3	2	2	2		
	Number of plants that collapsed in this period ...	3	*all*	*all*	*all*	*all*	*all*		
Cajanus ...	Period (in days) after which withering commenced ...	*	*	7	3	3	3	10	18
	Transpiration (in grams) in that time	15·5	12·2	10·5	2·2	3·0	2·0		
	Total period of growth (in days)	10	10	10	8	10	5		
	Number of plants that collapsed in this period ...	0	0	1	*all*	*all*	*all*		
Cotton ...	Period (in days) after which withering commenced ...	*	8	5	3	4†	2	10	12·5
	Transpiration (in grams) in that time	8·7	6·7	4·7	2·0	3·7	0		
	Total period of growth (in days)	10	10	8	8	10	8		
	Number of plants that collapsed in this period ...	0	*all*	*all*	*all*	1	*all*		
Sesamum ...	Period (in days) after which withering commenced ...	1	1	1	1	1	1	10	6·0
	Transpiration (in grams) in that time	0	0	0	0	0	0		
	Total period of growth (in days)	4	4	3	3	4	3		
	Number of plants that collapsed in this period ...	*all*	*all*	*all*	*all*	*all*	*all*		
Wheat ...	Period (in days) after which withering commenced ...	7	6	4½	4	4	3	10	7·0
	Transpiration (in grams) in that time	3·5	1·9	1·4	1·0	1·2	1·6		
	Total period of growth (in days)	10	10	10	10	10	10		
	Number of plants that collapsed in this period ...	2	1	2	1	2	*all*		
Gram ...	Period (in days) after which withering commenced ...	*	*	*	*	*	1	5	17·7
	Transpiration (in grams) in that time	6·5	6·2	4·7	2·7	4·5	2·7		
	Total period of growth (in days)	5	5	5	5	5	5		
	Number of plants that collapsed in this period ...	0		0	0	0	*all*		

* Plants did not wither at all.

† Though the cotton did not wither, it ceased to transpire after the 3rd day.

The data given in the table prove that all the plants tried, wither in the same order in the different solutions; thus all do worst in the "gram water," "sesamum water" being the next most toxic, followed in order by wheat, cotton, cajanus, sorghum.

This order could of course be easily changed by diluting any one or more of the solutions, the strengths of which in the experiment are quite arbitrary.

The fact of this regularity appears to favour the view put forward above that the substances excreted by various plants are dentical, and that the solutions used differ only in concentration and not in kind.

Nature of the Toxic Substance.

It was at first thought that the toxic matter might be an albumose or similar substance. The solutions, however, all gave negative results, on the application of the biuret and other tests for these compounds.

The fact that tannic acid precipitated and corrected the toxic material suggested the presence of an alkaloid.

It is interesting to note that leaves containing tannic acid are systematically used as manure in the spice gardens and rice fields of Canara* and that the cultivators' opinion as to the manurial value of the leaves of any particular variety of tree corresponds apparently to the amount of tannic acid contained in the leaf. Thus in the order of preference the leaves of the following trees (among others) are utilized in this way :—

Hirda (Terminalia chebula).
Matti (Do. tomentosa).
Honal (Do. paniculata).
Kanagal (Dillenia pentagyna).

That it is not the ash constituents of these leaves that produce the manurial effect is obvious from the fact that if the leaves be burnt and the ashes applied to pepper—one of the spices to

* Mollison—"Cultivation of Betel, Palm, Cardamom and Pepper in the Kanara District of the Bombay Presidency" (Bulletin No. 20 of the Department of Land Records and Agriculture, Bombay, 1900).

which the leaf manure is applied—the pepper vine is killed. Similarly neither irrigation nor farm-yard manure serves the purpose of the leaves; the latter therefore serves neither for storage and regulation of water nor as a supply of nitrogen.

It was indeed these facts that first suggested to me the possibility of the toxic substance being either an albuminous substance or an alkaloid for both of which tannic acid acts as a precipitant.

A preliminary examination of the solutions only has been as yet made, but this appears to prove that it is an alkaloid that is excreted by all the plants experimented with, and further that the substance is identical in all cases.

The solutions examined consisted of both well and distilled water in which plants had grown.

The principal reactions obtained are as follows:—

Phosphomolybdic acid	A white precipitate.
Phosphotungstic acid	Do. do.
Mayer's Reagent	Do. do.
Tannic acid	Do. do.
Platinum chloride	Precipitates on standing.
Iodised potassium iodide	
Mercuric chloride	A coagulated white precipitate.

The subtance is thrown down in concentrated solutions only as a white flocculent precipitate on adding caustic potash. A similar precipitate is thrown down immediately on adding potassium nitrate, potassium chloride, potassium sulphate or sodium chloride and after some time on adding sodium nitrate or sulphate. Potassium chloride and sulphate and sodium chloride produce coagulated precipitates and apparently precipitate the substance most completely of the reagents tried. The precipitate is insoluble in water, alcohol and all the usual organic solvents, but soluble in acids and alkalies. This precipitate can be titrated with an acid using methyl orange as indicator. It is therefore apparently the base itself and not a salt. The salt formed on titration is acid to litmus as is also distilled water in which plants have grown. This fact apparently accounts for statements that free acids or acid salts are exuded by plant roots. Further, on precipitation the solution becomes distinctly acid to methyl orange.

Ammonium sulphate and dilute sulphuric acid also cause precipitation (of the sulphate ?) of the substance after some time ; so also do sodium acetate, ammonium (but not sodium) phosphate, ammonium molybdate (with nitric acid), ferric chloride (soluble in acetic acid).

With greater concentration doubtless other substances than those here indicated would cause precipitation.

The substance cannot be separated out by shaking its ammoniated solution with amyl alcohol, chloroform, or either, hot or cold. It is also insoluble in alcohol.

The solution produces after a few minutes a blue precipitate (in a green solution) with a mixture of ferric chloride and potassium ferricyanide. It also decomposes potassium permanganate in the cold with production of a stable red precipitate (of the permanganate ?) destroyed by boiling or excess of the reagent. Reduction also takes place with Fehling's solution and with silver oxide in ammonia.

It is easily decomposed by heating at 100°C when in the solid state.

The solid dissolves in strong acids and Frohde's reagent without colour, except in the case of nitric acid which gives a yellow solution. Potassium bichromate after strong sulphuric acid gives a green colour, changing to blue.

The above reactions were given by all the solutions named in Table V and appear to indicate the identity of the toxic substance in the case of all plants.

The substance is present in the solution in combination with citric acid. I could find no trace of phosphate or formate as stated to exist by Czapek, though the original solution before elimination of the base, similates many of the reactions of these salts.

Without having reference to the current literature on the subject it is impossible to compare the reactions above given with those obtained with any of the known alkaloids. Its marked insolubility appears to differentiate it from all the commoner alkaloids except pseudomorphine and rhæodine with which it is improbable that it is identical.

The amount of substance given out by the roots is not inconsiderable. For instance, the precipitate obtained by adding potassium sulphate to a solution containing the excrement of 10 cotton plants growing until their combined air-dry weight was ·4 gramme, weighed, when dry, ·21 gramme.

Sesamum in its early stages of growth, appears actually to excrete a greater amount of material than it builds up in its own substance.

CONCLUSION.

The bearing of the phenomena described in this article on the question of rotation of crops is obvious.

The question may, however, be put why cotton, for instance, which grows so feebly *near* sorghum (Table IV) grows at least as well if not better, *after* sorghum than after cotton. From experiments now in progress it appears that this is explicable as follows :—

When cotton is growing near sorghum the roots of the latter exude the toxic substance into the soil in large quantities. This spreads rapidly through the soil into the subsoil especially during the rainy season, and neighbouring cotton plants are not protected by the fact that their tap roots go down far below the zone in which the sorghum roots are situated. When cotton follows sorghum, however, the condition of affairs is different ; the toxic substance remaining, at the time of harvesting, in the roots of the previous sorghum crop is now being given out slowly in the course of the decay of those roots,* and is held entangled in the organic matter of the roots, largely in the zone of soil in which the roots of sorghum spread. Each crop thus fouls the soil for a crop of the same variety, whose roots will take the same course as the previous crop, more than for a crop whose roots spread in another layer of the soil.

The precipitation of the toxic substance by most of the mineral manures in common use indicates the manner in which many manures act in increasing crop yields.

* That the roots of sorghum and other crops exert an extraordinarily toxic effect when mixed with soil in which plants are then grown has been proved by the writer in a set of pot experiments.

While this note has been going through the press I have received Bulletin No. 40 of the Bureau of Soils, (United States of America) by Messrs. Schreiner and Reed on "Some factors influencing soil fertility." In this Bulletin the authors come to the conclusion that "the excreta of the cow pea roots are very slightly toxic to roots of wheat seedlings" (page 35), and that "the excreta of oats are more toxic to the roots of wheat seedlings than those of corn or cow peas—a conclusion that is substantiated by the results obtained in crop rotations" (page 36).

The experimental data given in the Bulletin do not justify these conclusions but only indicate that the excreta from cow peas *when in the arbitrary concentration obtaining in their experiments* are very slightly toxic to roots of wheat seedlings *when these latter are at the stage of growth of those used in the experiment.*

I find that very young plants are not affected by a toxic solution of given strength so rapidly as older plants, doubtless because the latter, owing to more rapid transpiration, take in the toxic substance in larger quantities.

Again, the impossibility of the statement made with regard to the excreta of oats being more toxic than that of cow peas or corn is self-evident, implying as it does that any quantity *however great* from oats is more toxic than any quantity *however small* from cow peas or corn.

The media that were compared contained quite arbitrary amounts of excreta from an arbitrary number of plants growing for an arbitrary period, it being stated that "the agar containing their excretions was obtained in each case by planting a large number of seedlings in a dish of soft agar and allowing them to grow for eight to fifteen days according to the kind of plant employed."

There are no data in the Bulletin under reference which indicate that the excreta from all the plants tried are not identical in character.

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SOME EXPERIMENTS IN THE HYBRIDISING OF INDIAN COTTONS

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SOME EXPERIMENTS IN THE HYBRIDISING OF INDIAN COTTONS.

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EXPERIMENTS in crossing different varieties of cotton plants have often been made with the idea of uniting into one, the good qualities of two or more strains. Some reference to these may be found in Sir George Watt's book, "The wild and cultivated cotton plants of the world." The first experiments of which records have been made, were, he says,* perhaps those by Rohr, who more than a hundred years ago crossed some American fuzzy and clean seeded species, but did not apparently experiment with Indian cottons. In 1884, however, Dr. Alexander Burns of Broach crossed *Gossypium obtusifolium* var. *wightiana* [Guzerat cotton] with the red flowered *G. arboreum*, and obtained a plant having the good qualities of both parents. "The leaves were those of Arboreum, ...the flowers were red with a yellow throat" and the plant cropped early and produced a very silky floss. But nothing seems to be known about the subsequent history of this cross and the plant apparently died out. Major Trevor Clarke was, in the sixties, experimenting with Indian varieties, but I have been not able to find any record of his results.† In 1903, Professor Gammie,‡ of Poona, published a tentative classification of Indian cottons, and with this some account of crosses that he had made of Indian cottons, *inter se*

* Watt, Sir George, (1) "The wild and cultivated cotton plants of the world" 1907, p. 333 *et seq.*

† *Ibid*, p. 336.

‡ Gammie, G. A., (2) "Classification of the Indian cottons (tentative)" 1903, p. 15.

and also with the naturalised American "Dharwar" (*G. hirsutum*). His success in crossing the latter species with *Varadi*, with *Kumpta* and with *Nagpur* or *Kil*, varieties which belong to the great group of African-Asiatic species (Watt's section II of the genus *Gossypium*) proves that such hybrids are possible,* but they are difficult to obtain, and appear to be very unfertile, for he says of all that he obtained only one survived.† In his account too of the crosses made between Indian varieties themselves, he says nothing of the second and succeeding hybrid generations. Mr. F. Fletcher, in a Bulletin on Bombay cottons,‡ gave details of some crosses that had been made, but these like those of Prof. Gammie were with reference to the lint alone, and were not on Mendelian lines. The same worker had a note, later on, in the "*Journal of Agricultural Science*"§ on "Mendelian inheritance in cottons," in which he stated that dominance was shown in several characters, among others by the fineness, length and colour of the lint, (which I have also observed in another cross) by the yellow colour of the petals (over white) and by fuzziness of the seed over nakedness. But his figures were for the first and second generations only. That this would hold for later generations and that therefore Mendel's law was applicable was not shown. Mr. Lawrence Balls, who has been working on Egyptian cottons, has also published papers on the subject.‖ ¶ ** He believes that cross-fertilisation by insects occurs to a very considerable extent in the field, and in this he is in agreement

* Natural hybrids are occasionally found where "Indian" and American varieties are grown together. Sir George Watt considers *jowari* "to have arisen from such a natural cross. Watt, *ibid.*, pp. 338, 339.

† Gammie, G. A. (3) "The Indian Cottons," 1905.

‡ Fletcher, F. (4) Bulletin No. 26 of the Bombay Agricultural Department, 1907.

§ Fletcher, F. (5) "Mendelian Inheritance in Cottons," Journal of Agricultural Science, Vol. II, Dec. 1907, p. 281.

‖ Balls, W. Lawrence. (6) "Note on Mendelian Heredity in Cottons," *ibid.*, p. 216.

¶ (Idem). (7) "Studies of Egyptian Cotton," Year Book of the Khedival Agricultural Society, 1906.

** (Idem). (8) "Mendelian Studies of Egyptian Cotton," Journal of Agricultural Science, Vol. II, p. 347 *et seq.* (July 1908).

with Leake,* myself, and others, in regard to an entirely different set of plants, the Indian cottons. I became acquainted with his work, as also with Fletcher's and Leake's, only after the manuscript of this paper had been written, but I have referred in foot-notes to his and their results where they touch on mine. Mr. Leake published* after this was written, a note on the variation and inheritance of certain characters in cotton plants. He determined by measurement the factor $\frac{\text{length}}{\text{breadth}}$ of the lobes of a leaf, in a number of cases, and found that when a *G. indicum* having rather narrow lobes, was crossed with a *G. arboreum* with broader lobes, the hybrid was of an intermediate type. The next generation, he says, "contained, among others, plants with typical "broad"—and typical "narrow"—"lobed leaves," but he gives no statistics to show the numerical distribution of the different types, nor, as far as I know, has any full statistical account been published of experiments with cottons on Mendelian lines.

The experiments described in this paper, of which a preliminary account was sent to the "Director of Agriculture," Madras, in 1906, were begun in the autumn of 1904, soon after my arrival in India, with a view to determining whether the results of crossing Indian varieties of cotton plants, could be described by any "law," which would guide one in attempting to breed new and improved races, and whether any unit characters exist or can be found which can be passed on undiluted from one variety to another. My observations go to show that such unit characters do exist in both vegetative and floral organs. I have followed the behaviour of three such pairs, the rounded herbaceum or pointed neglectum, shape of leaf, the white or yellow colour of the flower, and the white fuzzy or black naked seed, for five generations, and from observations of some hundreds of plants (817 in the 4th generation, 1177 in the 5th) conclude that the characters studied do really segregate on Mendelian lines. Balls (18) and Fletcher†(4)

* Leake (9) "Studies in the Experimental Breeding of Indian Cottons," Journal of the Asiatic Society of Bengal. New Series, Vol. IV, 1908, No. 1.

† Fletcher, F. (4) Bulletin No. 26 of the Bombay Agricultural Department, 1907.

have anticipated me in the publishing of similar conclusions, with other varieties of Egyptian and Indian cottons, but these are based, as far as the published results show, on two generations only and on a much smaller number of plants.

The practical outcome of these observations appears to be that the cross-breeding of these varieties could be carried on with almost mathematical precision, and if, as seems likely, these principles apply to other characters as well, one might expect to obtain any desired type in a very few years.

As I could obtain no information as to what crosses would succeed, or would be likely to give useful or interesting results, I started with a few different kinds, the seed of which, from the Government farms at Bellary and elsewhere, was kindly given me by Mr. Charles Benson, at that time Deputy Director of Agriculture, Madras. They consisted of a red-flowered tree-cotton named *Karehathi*, *Jari* and *Bani* of the Central Provinces, *Jowari* (fuzzy and naked seeded) *Northerns Bilaihathi* and *Yerrapathi* of this Presidency. In addition, there were two races of American upland cottons, a naturalised "Kidney" tree-cotton, and another tree-cotton, related apparently to *G. peruvianum*. Hybrids were readily obtained by crossing these exotics *inter se*. From one of the American uplands (W. H. Cooke) and the tree-cotton (*G. peruvianum* were obtained a number of bushy plants very like some I saw grown from seed supplied by Messrs. Shaw, Wallace & Co. of Calcutta, as a new variety. The lint was long and silky and the plants were intermediate in size between the two parents, those from seed of bolls on the tree being slightly larger than those by the reverse cross but otherwise very similar.

As my concern was with the indigenous races, these and the other exotic hybrids were allowed to die out, but in the twenty plants of which I have notes, the red colour of the leaf stalks, and the pink spot at the base of the leaf-blade,*—characters belonging to the herbaceous parent, and the pink spot at the base of the

* Cf. also Balls (8).

petals, and the naked surface of the seed of the tree-cotton were dominant characters. This is so far interesting as the red colour of the leaf-stalks and the nakedness of the seed, were dominant also in totally different crosses between two Indian races.

The seeds were all sown in my garden in September 1904, and the Indian varieties came into flower two months later. The local races—*Northerns Bilaihathi Jowari* and *Yerrapathi*—had been grown for some years on the Government farm at Bellary, and might be considered pure. The ten or twelve plants in each bed appeared to be very similar. But among the *Jari* and the *Bani*, from the Central Provinces, were two plants having large yellow instead of small white flowers. Attempts to cross the two kinds of *Bani*—the yellow and the white flowered—were not successful, but the yellow flowered *Jari* was crossed with other plants. (Table II, No. 4.)

I found it necessary to remove the anthers early in the morning as soon as it was light (and even before daybreak in the case of the "Americans") as they mature and shed their pollen very early. Sir George Watt quotes* Major Trevor Clarke's advice to apply the pollen overnight, "*i.e.*, just before the flower has expanded or has been attacked by pollen-bearing insects." This advice would apply more to the American varieties than to those I was dealing with. I tried removing the anthers overnight, covering the styles, and pollinating them the next day, but gave this plan up, as it was difficult to know which flowers would open the next morning, and none of my crosses so made were successful. I am inclined, however, to think that evening is the best time for removing the anthers, as in the morning they are so nearly ripe, that they are liable to burst and shed the pollen while being removed, and I had to give up a large number of flowers on that account. All who have worked at cross-pollination of flowers, are, I believe, convinced of the extreme sensitiveness of the stigma,—Charles Darwin often insisted on this—and it

* Watt. (1) *Ibid*, p. 338.

was found almost impossible to remove grains from the stigma without injuring its receptiveness.

To emasculate a flower, the bracteoles and petals were first removed before the latter had opened, and the anthers cut off with a pair of fine pointed scissors, beginning from above and working downwards, so as to prevent them touching the stigma. It was then pollinated from some other plant and covered with a small paper bag, about 3 inches long and one inch wide, and a small label was attached to the flower-stalk, with the registered number. If not pollinated immediately it was covered and labelled and crossed later on in the day with pollen from a previously covered flower, and again covered with the paper bag. The number of the cross and of the parents were entered both on the label and in a book. My first pollinations were made in the mornings, but as the pollen did not then adhere well, I often left them till the afternoon.

The weather appears to exert a decided influence on the germination or fertility of the pollen grains. In the following table are given the numbers of cross-pollinations made, and of ripe bolls obtained from them, together with the average percentage of cloud in the sky, as determined at the Madras Observatory for the periods stated :—

TABLE I.

Periods........ days ending.			Number of pollinated styles.	Number of bolls.	%	Average cloud.
5 days to	Nov.	9 ...	17	2	12	40
Do.	do.	14 ...	34	5	14·7	53
Do.	do.	22 ...	—	—	—	30
———	do.	23 & 24 ...	35	12	34	09
5 days to	do.	29 ...	77	21	27·2	29
Do.	Dec.	4 ...	20	3	15	72
Do.	do.	9	6	1	16·6	49
Do.	do.	14 ...	22	6	27·3	37
Do.	do.	*19 ...	15	1	6·5	53*
Do.	do.	24 ...	—	—	—	—
Do.	do.	29 ...	8	1	12·5	40

That fine bright days are the best for setting of flowers, is, I believe, the experience of gardeners, and these figures amply

* Rain fell on the 18th to 21st.

bear this out. The highest % (34) of successful pollinations being when the average cloud was least (·09) and *pari passu* the more cloud the fewer fertilised bolls. Mr. Charles Benson told me that rain or even heavy dew would often cause half ripened bolls to drop, and a good many were lost, probably from this cause.

I collected the hybrid seeds myself, and after picking off the floss sowed them in pots from which the young plants were put out into beds, in February 1905. The uniformity of the crosses between *Jari* and the local "*herbaceums*" was very striking. They were all alike in having the red stems and petioles and narrow-lobed leaves of *Jari*, but had the full yellow flowers of *Jowari*, *Northerns* and *Bilai*. One lot, No. 3 in tables II and V and i. in table X came into boll in April, and by sowing seed at once, I obtained a second generation crop before the November rains. This was sown along with seed from the others on land hired near Madras, when I had, therefore, one lot a generation ahead of the others.

The plants of the first generation, with the exception of the lot just referred to (fig. 15) were all larger and more vigorous than their parents. This increased vigour was continued in the 2nd, 3rd and 4th generations, and was very marked. Those of each bed—*i.e.*, from each hybridised boll—were, as far as I could see, very much alike. In the 2nd generation, however, the utmost diversity appeared among the descendants of the *Jari* and "*herbaceum*" and *Bani* and "*herbaceum*" crosses. Some grew tall and straight, branching stiffly at right angles (fig. 16), others were low with spreading branches (fig. 17). Some had broad lobed leaves of the "*herbaceum*" or "*obtusifolium*" type, others had the long narrow pointed lobes of *Jari*. While, moreover, all in the first generation had yellow flowers, a considerable number of the 2nd generation from a white and yellow flower cross had pure white flowers. Some had short rounded bolls like those of the original *Jowari*, in others the bolls were long and pointed. Again, the short coarse nature of the lint (floss) of the *Jari* and *Bani* parents was absent in the first generation, but appeared in the second. And Mr. C. Benson drew my attention

to the similarity exhibited by some plants in one lot—from a cross between Bani and *Jowari*—to "American uplands," the broad flat leaves and spreading branches reminding one of that type.

The cotton plant appears to attract a large number of insects. Large red striped beetles bit through at the base of the flowers and destroyed the style. The latter too was often damaged in the bud by caterpillars. Boll-worms destroyed the seed, but the greatest damage was, I think, done by the "scarlet cotton-bug," and the small "dusky cotton-bug," which attacked the seed as soon as a boll opened, and were never got under, though a small boy was employed to go round and shake them off into a tin of paraffin. Any seeds that were left on the bushes were quickly eaten by ground vermin. They had, therefore, to be collected almost daily, and the picking from so many separate plants was very tedious. There was the further disadvantage that the field being some way out of the town, work there was necessarily intermittent, and the flowers and seeds of some plants were on that account never seen. The next year I was given by the authorities the use of land on a Government experimental farm, where my plants were well looked after by the manager, who also, while I was unavoidably absent from the country, made many of the notes on which I base the figures of the fourth generation.

But most of the seeds sown there failed to germinate. Cotton seed is known to keep badly during the hot weather if ginned, as mine were. Or it may be that in the damp atmosphere of Madras these seeds were never properly dried, and so were particularly susceptible to heat. The local Horticultural Society has always found that imported garden seed, especially those of an oily nature, rapidly deteriorate in germinating power. In my case over 8,000 seeds from selected plants of F. 2 were sown, but those that did come up were all washed out of the light sandy soil by a heavy fall of rain which occurred soon afterwards. The whole of these on which I was relying for my third generation were therefore wiped out, and I have to fall back on the 240 plants from F. 1, No. 3, referred to above as grown the previous season near Madras. This was the more unfortunate, as the characters

of the parent plants had been very carefully noted, and as these were still growing it was hoped to compare the new generation with them, while less attention had been paid to these other few plants.

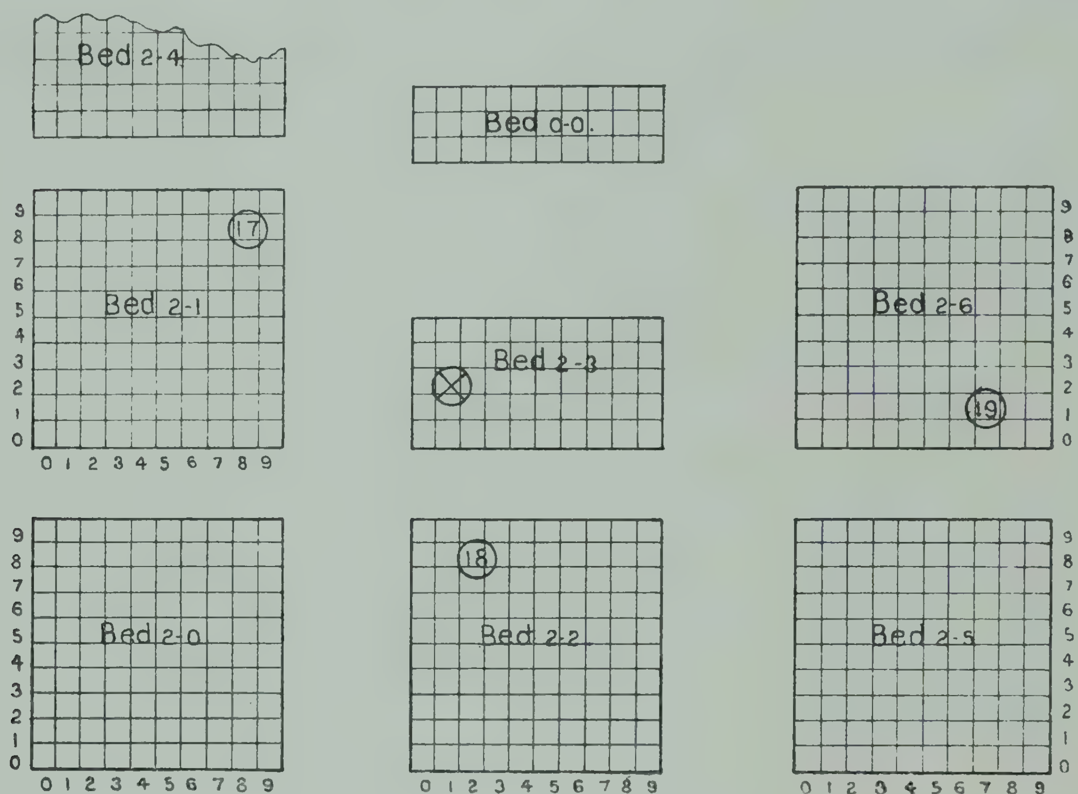
I had not made a point of collecting seed from the other lot, but sufficient had been taken from a few of the plants, for the fourth hybrid generation, and on another part of the farm enough were grown to indicate the distribution of the characters (tables IV, IX and XII).

ON THE ARRANGEMENT OF THE PLANTS.

The original plants and the first hybrid generation were set out in numbered beds and named by letters of the Greek alphabet. But as the number of plants which could be so named in any bed was thus limited, by the number of letters available, and the naming was somewhat cumbersome, I adopted for the second and subsequent generations another system, which I will shortly describe, as it is so well suited for work of this kind, and I have not seen anything similar referred to in accounts of breeding experiments.

The plants were arranged in rows, about two feet apart or more. In each row were 10 plants, and 10 rows constituted a rectangular bed. The rows were numbered 0 to 9, and the plants in each row, from left to right, also 0 to 9. No labels were affixed, except here and there, if experience showed on account of overcrowding or irregular growth, a plant might be wrongly numbered. Each plant in fact has a number depending only on its position in the bed, thus the 4th plant of the 6th row would be No. 53 of that bed. The first plant of the bed is 00. The last 99. The beds of any one lot were also numbered, and by using also the registered number of the whole lot of seeds, the position and origin of any plant was defined and could be easily and shortly written down. Thus fig. 16 is from the photograph of a plant No. 2321, *i.e.*, the second plant of the 3rd row in the 4th bed of lot 2, the position of which is shown in the plan (X). Fig. 17 is of No. 2188, the 9th plant of the 9th row of the 2nd bed of

the same lot. These are from photographs taken in the field. Fig. 18 is of a dried piece from No. 2282, fig. 19 of No. 2617.



Copy of part of the plan of the field to show method of numbering the plants for their identification by their position.

BED 2—0.

9	Y	P	Y	W	Y	Y	W	Y	W	Y
8	Y	P	Y	P	Y	W	W	P	W	P
7		W	Y	Y	Y	Y	W	Y	Y	Y
6	W	W	Y	Y	Y	Y	W	W	Y	Y
5	W	P	Y	P	W	P	P	W	Y	Y
4	W	P	W	W	W	Y	P	W	W	Y
3	W	P	Y	Y	Y	W	P	Y	W	P
2	Y	Y	W	W	P	Y	Y	Y	W	W
1	Y	Y		W	W	W	Y	W	P	Y
0	Y	W	Y	Y	Y	Y	Y	W	Y	W
	0	1	2	3	4	5	6	7	8	

Yellow flowers	...	...	47
Pale ,,	...	...	17
White ,,	...	...	34
Plants died	...	...	2

The taking of notes of the plants was also very much simplified by this system. A square ruled to 100 small squares represented a bed, each small square representing a plant. It is only necessary to write in the square some letter or symbol denoting the nature of the character noted. Thus the colours of the flowers in the bed marked 2-0 in the plan were noted as in the accompanying note-book plan of the bed.

THE LEAF.

Crosses were made between all the Indian races named above, but the two species which differed most in the shape of the leaf were *Jari* (*G. arboreum* Linn. var. *neglectum* of Watt ; *G. neglectum* Tod. of Gammie) and *G. obtusifolium* Roxb. (of Watt) or *G. herbaceum* Linn. (of Gammie) represented in my beds by *Northerns*, by fuzzy seeded (white) *Jowari*, by naked seeded (black) *Jowari* and by *Bilaihathi*. Figures 1, 2, 3, 4, show the characteristic shape of their leaves.

The following table gives the number of bolls and of plants obtained.

TABLE II.

Fig.	Seed plant.	Pollen plant.	Bolls.	Plants.	Leaves like.
1	Jowari fuzzy ...	Jari white flower ...	2	19	......
2	Jari white flower ...	Jowari fuzzy ...	1	11	Fig. 5
3	Jowari naked ...	Jari white flower ...	1	16	,, 6 & 7
4	Bilaihathi ...	,, yellow flower ...	2	16	,, 17
5	Northerns ...	,, white flower ...	4	58	,, 8
6	Jari white flower ...	Northerns	1	11	,, 9
		Total ...	11	131	

All these 131 plants were without exception like *Jari* in the shape of the leaf.* Figures 5 to 9 were drawn to scale from

* It might appear that my observations are here at variance with those of Leake who (9 p. 15) says the hybrids he obtained were intermediate between the parents. But his crosses were between *G. arboreum* and *G. indicum*, while mine were between *G. neglectum* and *G. herbaceum*, species which are probably less closely connected. The cases are, therefore, not analogous, nor the observations necessarily contradictory.

representative leaves. The uniformity of the plants of a bed was most striking: this was particularly the case with lot No. 3, which were all small plants and sparingly branched like their *Jari* parent, with large bright yellow flowers like *Jowari* (fig. 15).

Seed was collected from these beds during the months April to August, and from lot No. 3, which were the earliest, some were sown in April. It is from this lot that the plants of the 3rd and 4th generations of this cross were raised. The others were sown in September in small seed-beds and planted out in rows and beds as explained above.

It was at once seen that the *herbaceum* (of Gammie) type of leaf, of which there was no sign in the first generation, (fig. 15) had reappeared in its original form in a large number of plants of the next.

Of those of No. 3, out of 620 plants 370 had leaves like *Jari*, 128 like *Jowari*, 121 more or less intermediate. That is to say 21% had the character which was not present in the first hybrid generation.

From No. 4, of 102 plants 54 were like *Jari* and 22 like the *herbaceum*, a percentage of 21·6. Of lot No. 5 however a larger proportion were classed as intermediate—of 163 plants 114 were like *Jari*, 33 intermediate, and 16 *herbaceums*. I refer only to the general form of the leaf. *Jari* and *Jowari* leaves differ also in texture and surface, but it was difficult in the short time available to discriminate these characters. Some classed above as like *Jari* had for instance even narrower lobes, and had the soft feel and surface of *Jowari*. In a few the margins of the leaves were waved, a strikingly exaggerated instance of this being shown in fig. 10.

Table III shows the behaviour of the plants from *neglectum* (*Jari*-like), and of the *herbaceum* or *Jowari*-like plants in the next generation.

Table III.

The third hybrid generation.

No.	Parents' Leaf.	Negl.	Herb.	Total. N.	Total. H.
1	neglectum	7	...	.	...
2	do.	10	...	...	..
3	do.	6	...	..	...
4	do.	6	...	..	...
5	do.	20	...	49	0
6	do.	17	5	...	...
7	do.	6	3	...	..
8	do.	12	5	..	...
9	do.	23	5	58	18
10	do.	?	?	.	...
11	do.	?	?	...	...
12	do.	?	?	...	...
13	herbaceum	...	30	...	...
14	do.	...	26	...	...
15	do.	1	20	...	...
16	do.	...	8	1	84

Nos. 1 to 5 appear to have been, as regards the shape of the leaf, pure *neglectums;* my impression is that the progeny of Nos. 10—12 were also all *neglectums,* but as it was not intended to deduce the distribution of characters from this lot,* no notes were made of their leaves. They are introduced here as notes were made of their flowers and seed.

The other '*neglectum*-leafed' parents (Nos. 6 to 9) gave out of 76 plants, noted, 18 *herbaceums*, which is almost exactly the Mendelian expectation ($\frac{1}{4}$ of $76 = 19$). Nos. 13 to 16 bred practically true to the *herbaceum* character, there being only one stray *neglectum* among 85 plants.

* See page 8.

Table IV.

The fourth hybrid generation.

No.	Parent.	Negl.	Herb.	Negl.	Herb.
1	neglectum	13	...	...	...
2	do.	138	...	...	...
3	do.	6	...	157	0
4	do.	37	3	...	...
5	do.	67	7	...	...
6	do.	15	5	...	...
7	do.	7	6	...	...
8	do.	36	10	...	...
9	do.	94	16	...	...
10	do.	60	67	...	...
11	do.	12	7	328	121
12	do.	*1*	*9**	...	...
13	do.	*4*	*2*	...	...
14	do.	*8*	*19*	...	...
15	intermediate or herbaceum ...	5	40	...	...
16	do. do. ...	4	20	...	...
17	do. do. ...	3	20	...	...
18	do. do. ...	1	53	...	...
19	do. do. ..	3	62	16	195

In the fourth generation a similar distribution holds. Three of the *neglectums* were pure dominants. Nos. 4 to 11 gave out of 449 plants, 121 recessives. Theoretically the number of these should be 112. The last five were probably pure *herbaceums*. But they stood amongst *neglectums*, to crossing with which the 8% of *neglectums* are probably due.

Table V.

The fifth hybrid generation.

No.	No. in table IV.	Leaves of Grandparent.	Leaves of Parent.	Negl.	Herb.	Totals. N.	Totals. H.
1	2	neglectum ...	neglectum ...	218	1	...	...
2	6	do. ...	do. ...	38	0	...	...
3	8	do. ...	do. ...	73	0	...	...
4	9	do. ...	do. ...	86	0	...	...
5	12	do. ...	do. ...	20	0	...	...
6	13	do. ...	do. ...	46	0	481	1
7	6	do. ...	do. ...	15	5	...	...
8	8	do. ...	do. ...	15	6	...	...
9	9	do. ...	do. ..	38	5	...	...
10	12	do. ...	do. ...	7	3	...	...
11	16	intermediate ...	do. ...	6	11	91	30
12	8	neglectum ...	herbaceum ...	1	10	...	...
13	16	intermediate ...	do. ...	6	135	...	...
14	18	do. ...	do. ...	1	334	...	...
15	19	do. ...	do. ...	1	181	8	639

* These numbers are not included in the totals, as they represent only a few plants out of a much larger number of seeds sown, and no importance can therefore be properly attached to them. But some of the plants are the parents of some in the next table.

The second column of figures refers to the number of the parent in table IV.

The parents in lots 1 to 6 appear to have been pure *neglectums*, for with the exception of one stray plant in line 1, all the offspring were *neglectums*. Those of lots 6 to 11 were hybrids and the proportion of *herbaceums*—30 out of 121—is exactly the expected Mendelian ratio of one-fourth. There are a few *neglectums* among the offspring of *herbaceum* parents (lots 12 to 15), but four of them were in one bed, and the rest may perhaps safely be taken as accidental inclusions. We see therefore that among plants of the fourth generation, as of the two preceding, there were two kinds of *neglectums*—pure and hybrid, the offspring of the latter showing the dominant and recessive characters in the proportion of 3 to 1.

THE FLOWER.

Most of the Indian varieties of cotton plants have yellow flowers, marked in the centre with red or purple, which in the evening fade to a terra-cotta colour. But two of the varieties with which I began these had comparatively small white flowers, marked also with purple, but fading to a pink colour. These were the white flowered *Jari* and *Bani*. Thirteen successfully crossed bolls were obtained between white and yellow flowered indigenous races thus :—

TABLE VI.

	Seed Plant.	Pollen Plant.	Bolls.	Yellow.	White.
1	Jowari	Jari	2	19	...
2	Jari	Jowari	1	11	..
3	Jowari	Jari	1	16	...
4	Northerns ...	Do.	4	58	...
5	Jari	Northerns ...	1	11	...
6	Jowari	Bani	3	24	...
7	Bani	Jowari	1	16	...
8	......	......	...	...	...
		Total ...	13	155	0

The flowers all appeared when fresh to be of a full yellow colour and not intermediate in tint or size between those of the

parents, and whether the yellow colour was supplied by pollen or by the ovule made no difference.

In the next generation, however, there were many plants with perfectly white flowers exactly like their *Jari* or *Bani* grandparents, and also some of a pale colour. In some cases these were observed to fade to a terra-cotta colour like the yellow flowers, in others to turn pink like the white flowers. The yellow and pale flowers were large and open like the "*herbaceums*," and a few of the white were also large. But nearly all the white flowers were small and like those of *Jari* in shape, and there were no small yellow flowers observed.

The following is the distribution of flowers in the next generation :—

TABLE VII.

Second hybrid generation.

No.	F.	Yellow.	Pale.	White.	% White.
1	3	287	110	178	31
2	5	25	5	27	...
3	6	182	15	85	30·2
4	6	83	10	57	...
5	6	76	8	32	...
6	6	35	0	11	...
7	6	41	8	21	...
	Total ...	729	156	411	31·6

In some beds notes were not made of the flowers of all the plants, for some did not appear to flower at all, others only seldom, and continuous work not being possible, these latter were sometimes missed.

TABLE VIII.

The third hybrid generation.

No.	Number in table III.	Parent.	Yellow.	Pale.	White.	TOTALS. Y.	P.	W.
1	10	Yellow ...	21	...	...	21	0	0
2	8	Do. ...	25	...	11			
3	12	Do. ...	25	1	2			
4	5	Do. ...	13	...	3			
5	11	Do. ...	10	...	6			
6	7	Do. ...	7	...	2	80	1	24
7	13	Do. ...	*12*	...	*1**			
8	14	Do. ...	*6*	...	*7**			
9	3	Do. ...	*2*	...	*1**			
10	9	Pale ...	18	7	9	18	7	9
11	1	White ...	1	...	6			
12	6	Do. ...	...	...	22			
13	2	Do. ...	1	...	8			
14	15	Do. ...	...	...	9			
15	4	Do. ...	...	...	6	2	0	51
16	15	Do. ...	...	*1*	*10*			

The first plant (Table III, No. 10) was evidently a pure yellow. Nos. 2 to 6 gave 23% whites, 76% yellows. Of Nos. 7, 8 and 9 of this table, not enough plants were observed in flower to give full numbers, but they were evidently hybrid yellows.

The white-flowered plants gave nearly all whites. No. 15 (Table III, No. 4) was, as regards leaf and flower, a pure *Jari*.

TABLE IX.

The fourth hybrid generation.

No.	Grandparent.	Parent.	Yellow.	Pale.	White.	TOTALS. Y.	P.	W.
1	Yellow ...	Yellow ...	20	..	...	20	0	0
2	Do. ...	Do. ...	76	6	4			
3	Do. ...	Do. ...	11	...	4			
4	Do. ...	Do. ...	47	...	13			
5	Do. ...	Do. ...	26	...	10			
6	Do. ...	Do. ...	50	...	21			
7	Do. ...	Do. ...	5	13	1			
8	Do. ...	Do. ...	37	3	12			
9	Do. ...	Do. ...	72	...	45			
10	Pale ...	Do. ...	33	...	11			
11	Do. ...	Do. ...	82	13	37			
12	Do. ...	Do. ...	30	6	10	469	41	166
13	Do. ...	Pale ...	10	2	1			
14	Do. ..	Do. ...	3	1	2			
15	Do. ...	Do. ...	2	...	10			
16	Do. ...	Do. ...	14	2	8	29	5	21
17	Yellow ...	White ...	*5*	*0*	*2*			
18	Do. ...	Do. ...	*5*	*1*	*2*			
19	Do. ..	Do. ...	...	...	27	0	0	27

* These were all that were observed in flower, of a much larger number of actual plants growing; they are therefore not included in the total. It is fair to point out, that if they were

No. 1 appears to have been a pure yellow, and No. 19 a pure white-flowered plant. Nos. 2 to 12 gave between them, out of a total of 676, 166 whites or 24·2% of recessives. On the Mendelian theory, the number should have been 169—a very close approximation.

TABLE X.

The fifth hybrid generation.

No.	No. in table IV.	Grandparent.	Parent.	Yellow.	White.	TOTALS.	
						Y.	W.
1	2	Yellow ...	Yellow ...	13	..	...	..
2	8	Do. ...	Do. ...	13	..	...	...
3	9	Do. ...	Do. ...	9	...	...	...
4	15	Do. ...	Do. ...	28	...	...	...
5	18	Do. ...	Do. ...	53	...	116	0
6	2	Do. ...	Do. ...	129	54	...	...
7	8	Do. ...	Do. ...	108	44	...	...
8	9	Do. ...	Do. ...	26	6	...	...
9	15	Do. ...	Do. ...	177	58	...	...
10	16	Do. ...	Do. ...	83	27	...	...
11	18	Do. ...	Do. ...	90	26	613	215
12	2	Do. ...	White ...	1	81	...	...
13	6	Do. ...	Do. ...	...	6	...	...
14	8	Do. ...	Do. ...	...	6	...	...
15	9	Do. ...	Do. ...	...	5	...	...
16	18	Do. ...	Do. ...	1	2	...	...
17	19	Do. ...	Do. ...	1	86	3	193
18	13	White ...	Do. ...	3	41	..	...
19	..	Do. ...	Do. ...	1	31	4	72

The difference between yellow and white flowered plants is again plainly shown. The first five plants were pure yellows, and gave not a single white in over a hundred plants. The next six were hybrid yellows, and from them out of 828 plants 215 or 26 % were whites, a very close approximation to the expected ratio of 25 %. Extracted whites gave of nearly 200 plants, only 1·5 % yellows. The last two plants were in small beds among yellows to vicinism with which the yellows among them are probably due.

THE SEED.

Cotton seeds differ in shape, in size, and in colour—*i.e.*, after removal of the "floss" or "lint" the surface may be

included, the proportion of white to yellow or pale—33 to 101—would be almost exactly the expected Mendelian ratio of 1 to 3.

glabrous and black, or be covered by a more or less dense coating of short hairs, the "velvet" or "fuzz." Size is not a character easily discriminated, as it may depend on several factors. There is more real difference in the shape, the seeds of *Jowari* being for instance round, with a hard prominent beak. But attacks of seed-sucking insects, particularly of the Scarlet Bug (*Dysdercus cingulatus*), and the Dusky cotton-bug (*Oxycaraenus laetus*) so altered the shape, that attempts to discriminate between the seeds in this respect were given up. One variety—*Tellapatti* or black seeded *Jowari* differs from all the other Indian kinds, by having a smooth glabrous seed coat of a dark brown or black colour. Sir George Watt in his book (1) p. 152, says of this "There would seem little doubt that this is a naturally produced hybrid between the *uppam* and Bourbon cottons" and "the same seed on germination may produce" some or more fuzz. The possibility of its being such a hybrid had not occurred to me, for I looked upon it as a variety merely of the white or fuzzy *Jowari*. Nor, as far as I can see, does Prof. Gammie in his classification of Indian cottons (1903-1904 and 1905) give a hint of such an origin. Crosses were made of this race with the normal fuzzy *Jowari*, and with *Jari*.

Table XI shows the numbers of bolls and of plants obtained from them.

TABLE XI.

Bolls.	Seed Parent.	Pollen Parent.	Naked.	Inter.	Velvet.
a	Jowari fuzzy ...	Jowari naked ...	5	0	0
b	Do. do. ...	do. do. ...	16	0	0
c	Do. do. ...	do. do. ...	0	11	0
d	Do. do. ...	do. do. ...	0	0	10
e	Do. naked ...	do. fuzzy ...	6	0	1
f	Do. do. ...	do. do. ...	12	0	0
g	Do. do. ...	do. do. ...	0	12	0
h	Do. do. ...	do. do. ...	16	0	0
i=3	Do. do. ...	Jari	16	0	0
		Total ...	71	23	11

With the exception of boll "d," and of one plant out of boll "e," no fuzzy-seeded plants were obtained in the first generation by crossing the two kinds. These exceptions must, I think,

be taken as due to self-pollination, and to be not hybrids at all. The seeds of the plants from "c" were very nearly naked, and of those from "g," I have a note that though not quite clean, they were very like those of *Tellapatti*. Leaving "c" out of account therefore 8 bolls gave between them 95 plants,—71 having perfectly naked seeds, 23 nearly naked, and 1 fuzzy seed. As "i" which was the same as Table II No. 3, in previous table, was the most interesting cross on the whole, and also the most prolific in seed, attention was mainly directed to its progeny.

In the next generation, F. 2, many of the plants again had perfectly clean black seeds, but in others it was covered with a fuzz, as dense or even denser than that of the original *Jari* parent. Most of the plants could easily be classified as having naked or "fuzzy" seeds, but there were differences in the thickness of the covering, and in some the black seed-coat could be seen through it.

A considerable number were nearly naked, having varying quantities of short fuzzy hairs – either as a tuft at one or both ends, or extending half over the surface of the seed.

I divided them therefore into four groups. Those of No. 3 (Boll i) were as follows :—

Naked	207
Nearly naked	69
Thinly fuzzy	13
Fuzzy	304

There were fewer intermediates in the plants of the third generation, the distribution being as in Table XII.

TABLE XII.

The third hybrid generation.

No.	No. in Table III.	Parent.	Naked.	Inter.	Fuzzy.	TOTALS. N.	I.	F.
1	16	Naked ...	8	...	...	8	0	0
2	2	Do. ...	9	1	...			
3	6	Do. ...	16	3	...			
4	8	Do. ...	19	6	10			
5	12	Do. ...	16	6	7			
6	1	Do. ...	4	...	3	64	16	20
7	5	Do. ...	*6*	...	*11*[*]			
8	4	Do. ...	*3*	...	...			
9	7	Intermediate ...	2	1	5	2	1	5
10	9	Fuzzy ...	...	3	31			
11	11	Do. ...	...	1	16			
12	10	Do. ...	...	1	20			
13	4	Do. ...	...	...	6			
14	5	Do. ...	...	...	16	0	5	89
15	14	Do. ...	...	...	*8*			

The first on the list was a pure clean or naked-seeded plant. Of the next five, 20% were quite fuzzy, 64% quite naked.

From the really fuzzy seed, no naked-seeded plants were got, but there were about 5% of plants whose seed had a thin fuzz with black seed coat underneath.

TABLE XIII.

The fourth hybrid generation.

No.	Grandparent.	Parent.	Naked.	Inter.	Fuzzy.	TOTALS. N.	I.	F.
1	Naked ...	Naked ...	7	...	4			
2	Do. ...	Do. ...	14	2	2	21	2	6
3	Intermediate ...	Do. ...	*20*	*3*	*20*			
4	Do. ...	Do. ...	*2*	*1*	*6*			
5	Do. ...	Do. ...	1	...	4			
6	Do. ...	Intermediate ...	*3*	...	*11*			
7	Do. ...	Do. ...	31	7	36			
8	Do. ...	Do. ...	10	5	21	41	12	57
9	Naked ...	Fuzzy .	...	...	29			
10	Do. ..	Do. ...	...	1	55			
11	Do. ...	Do. ...	...	...	7			
12	Do. ...	Do. ...	...	...	8			
13	Do. ...	Do. ...	...	...	45			
14	Do. ...	Do. ...	2	3	105			
15	Do. ...	Do. ...	2	...	22	2	4	249
16	Fuzzy ...	Do.	...	1	65			
17	Do. ...	Do. ...	1	...	38			
18	Do. ...	Do. ...	...	...	6			
19	Do. ...	Do. ..	...	...	12	1	1	121

[*] Figures in italics mean that these were all that were observed of a much larger number.

Of Nos. 1 and 2, rather less than one quarter were fuzzy-seeded. The small proportion of naked and intermediates among those of fuzzy-seeded parents, whether extracted from naked grandparents or not, is very striking and in marked contrast to others. Intermediates appear to give about half naked and half fuzzy.

Table XIV.

The fifth hybrid generation.

No.	No. in table IV.	Grand parent.	Parent.	Naked.	Fuzzy.	Totals. N.	Totals. V.
1	8	Naked ..	Naked ...	4	...		
2	9	Do. ...	Do. ...	6	...	10	0
3	2	Do. ..	Do. ...	7	4		
4	8	Do. ...	Do. ...	6	2	13	6
5	8	Do. ...	Fuzzy ...	8	25	8	25
6	8	Do. ...	Do. ...	1	135	1	135
7	2	Fuzzy ...	Do. ...	...	129		
8	2	Do. ...	Do. ...	6	122		
9	9	Do. ...	Do. ...	...	5		
10	13	Do. ...	Do. ...	...	68		
11	15	Do. ...	Do. ...	2	259		
12	16	Do. ...	Do. ...	8	97		
13	16	Do. ...	Do. ...	...	24		
14	18	Do. ...	Do. ...	1	138		
15	19	Do. ...	Do. ...	...	87	17	929

The first two were probably pure naked-seeded plants, the next two hybrids. There was apparently a certain amount of intercrossing with naked-seeded plants growing near by, but on the whole the velvet seeds came very fairly pure to their kind. Except in the case of Nos. 5, 8 and 12, there were either no naked-seeded plants at all or less than 1%.

SUMMARY AND CONCLUSIONS.

The first and most obvious result of crossing was a great increase in the size and vigour of the plants. This is in accordance with general experience. In the cross *Jowari* × *Jari* the results of which form the substance of this paper, the first hybrid generation, the immediate results of the crossing were indeed small plants (fig. 11), but the next and succeeding generations contained some which were large bushes running up to six or

seven feet in height.* In other cases this increase in vigour was evident from the first. On the whole, too, the plants bolled freely and bore well, though some of the third generation of lot No. 3 were very poor. The smaller and *neglectum*-leaved plants came into bearing first, and two were especially marked in this respect, bearing heavily while the majority were still only in flower. As their seeds were naked and had long and silky staple, it was hoped that they might prove the progenitors of a useful variety, but as explained above (p. 8) none of the seeds of that lot survived.

Secondly, the plants were in some cases very variable, as is often observed with hybrids, Charles Darwin calling attention† to this in "animals and plants." According to the pure Mendelian theory, while the individual unit characters may change places, and combine in every way that chance may direct, so that the plants as a whole appear variable, each unit character should appear in itself true. In the shape of the leaf I found considerable variation, the lobes of some *neglectums* being very narrow, almost linear, and a few had wavy margins not unlike those of Assam cotton figured by Watt.‡ These might be due to different combinations § of *Allelomorphs*, but since wavy margins do not occur in the normal leaves of either *Jari* or *Jowari*, and appeared less frequently in later generations, I am inclined to consider them as monstrosities due to variation induced by hybridisation and by change of climate and soil. There is a general tendency too, for plants to approximate in character with age : in those more than twelve months old it is very difficult often to specify the nature of the leaf, or of the branching, and to this must be put down the failure to determine the characters of the lots Nos. 10, 11 and 12 of Table III. See fig. 7 and compare with figs. 11 and 12.

* My original *Jari* plants were small. Balls (8) notes a similar "intensification" of characters.

† Darwin, C. Variation in Animals and Plants under Domestication, 1868, ed. Vol. II, pp. 264, 266, 267.

‡ Watt *ibid.* (1) plate 18. Opp. p. 108.

§ Bateson and Saunders, (11) Report to the Evolution Committee of the Royal Society, p. 144.

THE INTERPRETATION OF THE RESULTS.

It is generally considered that flowers of cotton plants are habitually self-fertilised. Sir George Watt quotes the Danish colonist Rohr* as observing in 1790 that "Fecundation ordinarily takes place in *Gossypium*" before the flower has fully expanded : the same writer later on speaks hopefully of hybridising experiments with cotton,—"a plant that through the early maturity of its stamens (as in Mendel's classic experiments with *Pisum sativum*) is fully under control." † Mr. Charles Benson told me as the result of his long experience of cotton in Southern India, that it is practically always self-fertilised. Other officers of the Agricultural Department have said the same, pointing out that the ryots usually sow mixed seed, and that the absence of intermediate forms shows that crossing does not occur.

Professor Gammie, in his classification of Indian cottons, 1903 and 1905, emphasised the same point. For these reasons it was not thought necessary to cover the flowers, to make sure of obtaining self-fertilised seed for the second and subsequent generations. It would, moreover, have entailed more time and labour than I could give. A few flowers in the first hybrid generation were covered, but the plants so obtained (Bed. 0·0) did not show any less variation than those from uncovered flowers. Yet I think that a certain amount of crossing‡ did occur with my plants, the result of which was most apparent in the offspring of the first hybrid families, the latter being each of a few plants only and in beds close together. The presence of the few yellow flowers in a bed which one would expect to be all white and of *neglectum* leaves among *herbaceums* may, I think, have been due to accidental inter-crossing by the insects which visited the flowers in large numbers. Such inter-crossing almost certainly does occur even if only rarely, among cottons in the field. Mr. Sampson, the Deputy Director of Agriculture, pointed out to

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* Watt, (1)., p. 338.

† *Ibid*, p. 341.

‡ Compare also Shull (13) "On Mendelian inheritance of sunflowers." *Botanical Gazette*, Vol. XLV, No. 2, Feb. 1908, p. 106.

me several plants among Karanganis (*G. obtusifolium* Roxb. of Gammie) which showed characters belonging to Uppam (*G. herbaceum* Linn. of Gammie) and Karangani-like plants among Uppams, and there was one which seemed to be a natural cross between "American" type. If these were not natural crosses they were very remarkable instances of variation.*

THEORETICAL.

Though in some cases a considerable proportion of the seeds sown did not produce plants, one may reasonably suppose those that did, to be a fair sample of the lot. There is no *a priori* reason why seeds carrying a "*herbaceum*" leaf character should germinate better than those of the other kind, or that they should have done so, for instance in lots Nos. 13 to 16 of table 3 and not in lots Nos. 1 to 5 ; and when out of 676 plants (table IX) 166 or nearly 25 per cent. are of one type, this may fairly be considered to have been the proportion of all the seeds sown. Unless this is conceded no conclusion can be drawn from observations of a statistical kind, for one cannot well sow *all* the seeds of a plant, and of every batch of seeds some always fail.

Of the characters observed, two pairs, the *herbaceum* or *neglectum* shape of the leaf, and the white or yellow colour of the flowers, appear to segregate on Mendelian lines. Yellow is dominant over white, a fact which bears out C. Darwin's observation that characters common to a number of species are usually prepotent over those belonging to a few only, for nearly all species of *Gossypium* have yellow flowers.† In this connection it is also interesting to note that in crosses between coloured and white varieties of other genera, it has been found that white is in some cases dominant ; in others recessive ; and that this appears to depend on the way in which the colour is contained in the cells, Bateson in fact distinguishes two kinds of yellow

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* Since the above was written Leake (9) has expressed the opinion that crossing by insects is quite common.

† Balls (8) p. 363 and Fletcher (5) also find red dominant over yellow ; and cf. with reference to Alex. Burn and Watt's view of the antiquity of *G. arboreum* (1) p. 86.

coloration.* In Stocks (*Mathiola*) yellow is recessive, as Correns also found in crosses between a white *Polemonium cœruleum* and *P. Flavum*, and in these the colour is contained in plastids.†

In *Verbascum blattaria* L., Shull‡ finds yellow dominant, and here the colour is dissolved in the cell sap. Microscopic examination shows that with cottons in which, too, yellow is dominant it is a sap colour.

The *neglectum* (*arboreum*) shape of leaf is dominant over the *herbaceum*, and if we suppose that here again it is the phylogenetically older character which is dominant, this fact would confirm Sir George Watt's view that " *G. arboreum* Linn. if not an original wild stock, and therefore botanically a species, is remarkably near to what we are justified in believing, may have been one of the ancestral stocks of many of the cultivated cotton plants of the Old World § and that by cultivation was produced from the original *G. arboreum*, the annual plant now known as *G. herbaceum.*"||

The seed-coat does not appear to behave in exactly the same way : looking at a collection of seeds, from each plant of a bed, one would say at once that the " fuzzy " and " naked " characters obviously segregate. But closer observation shows that there are intermediate grades of " fuzzyness." It may be that these characters really do segregate in the same way as other varietal differences, but are influenced by external conditions, for Fletcher¶ found that in cottons of other species irrigation tends to make the seeds naked.** Or it may be that these characters are "*poikilodynamic*," and while separating in the germ cells, as

* Bateson (W.). Saunders (Miss E. R.) and Punnett (R. C.) Reports to the Evolution Committee of the Royal Society II and III, 1905 and 1906.

† Correns (C.). Weitere Beitrage zur Kenntniss der dominerenden Merkmaale und der Mosaik-bildung der " Bastarde " Ber. Dentsch. Bot. Gesells. 21 : s. 195—201. 1903, quoted by Shull (13).

‡ Shull (13), p. 115.

§ Watt (1), p. 86.

|| Watt *ibid*, p. 323.

¶ Fletcher Review of Sir George Watt's Book (1) Nature, Jan. 1908 : Vol. 77, p. 242.

** Among Egyptian cottons Balls finds, on the other hand, much fuzz dominant over little fuzz, and Fletcher (5) in another pair of Indian varieties that fuzz is dominant Neither worker gives details of more than two generations.

unit characters do, are of varying power, so that when combined in the hybrid, the dominance of the one (naked) is not always complete. This sort of thing occurs for instance (according to Shull) (13) in the branching of the sunflower.

Other characters also appeared to segregate, but their behaviour could not be followed after the second hybrid generation, on account of the failure of the third. But as far as the two generations showed, length and fineness of lint were dominant over the short and rough woolly nature, and the habit of the bolls opening widely as in fig. 16 and allowing the seeds to hang down freely (and so be collected cleanly) dominant over that of opening only a little.

If this be so, these important characters like the others of which this has been shown, could be bred into our Indian races of cotton plants without much difficulty.

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DESCRIPTION OF FIGURES.

Figs. 1 to 10 are from tracings made of normal leaves.

Fig. 1. "Jowari" (G. herbaceum).

Fig. 2. ,, ,,

Fig. 3. "Northerns" ,,

Fig. 4. Jari (G. neglectum).

Fig. 5. Cross Jari × Jowari (No. 2 of Table II).

Fig. 6. ,, Jowari × Jari (No. 3 ,, II).

Fig. 7. Leaves on young and old stems of the same cross as No. 6.

Fig. 8. Cross Northerns × Jari (No. 5 of Table II).

Fig. 9. ,, Jari × Northerns (No. 6 ,, II).

Fig. 10. Abnormal leaves in the second generation hybrid of Jowari × Jari.

Figs. 11 to 18 are from photographs 15, 16 and 17 of living plants, the others of herbarium material.

Fig. 11. Young plant of Jari.

Fig. 12. From an older plant of Jari.

Fig. 13. Northerns.

Fig. 14. Cross Bilai × Jari.

Fig. 15. A row of Jowari × Jari hybrid (No. 3). Showing the similarity of the plants in height and in their leaves, Some of the flowers have been covered by paper bags and labelled. Behind and parallel to it, is a row of cross No. 5.—(Northerns × Jari), and behind these at right angles a row of pure Jari, and two young tree cottons nearer to the right.

Fig. 16. Part of plant No. 2321. The lower branches ascend the upper are stiffly at right angles (the middle one on the left hand side was broken), the characteristic "neglectum" leaves and the opening of the bolls are clearly shown.

Fig. 17. Part of plant No. 2188, the branches are less stiff, and the leaves quite different.

Fig. 18. Part of plant No. 2282 (herbarium material).

Fig. 19. ,, ,, 2617 (,, ,,).

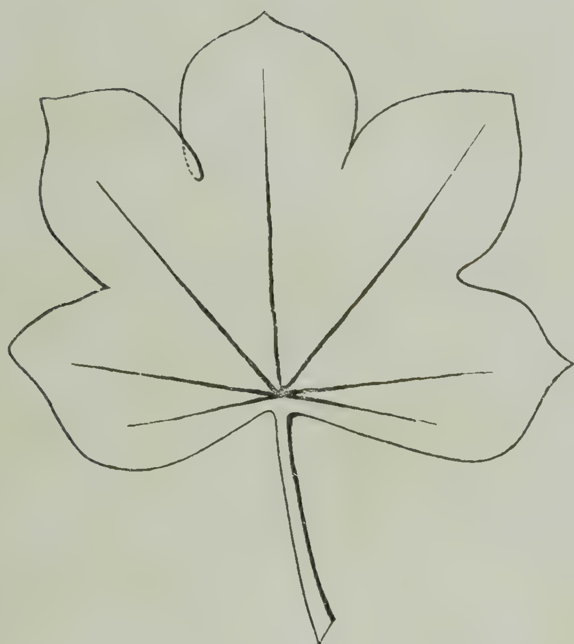

Fig. 1.

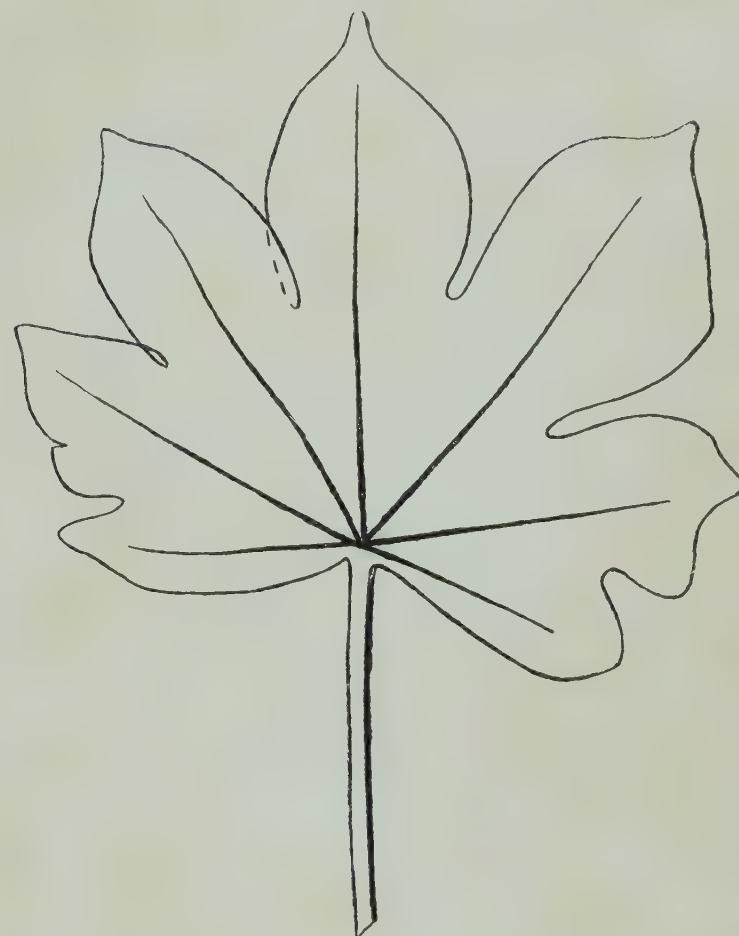

Fig. 2.

Fig. 3.

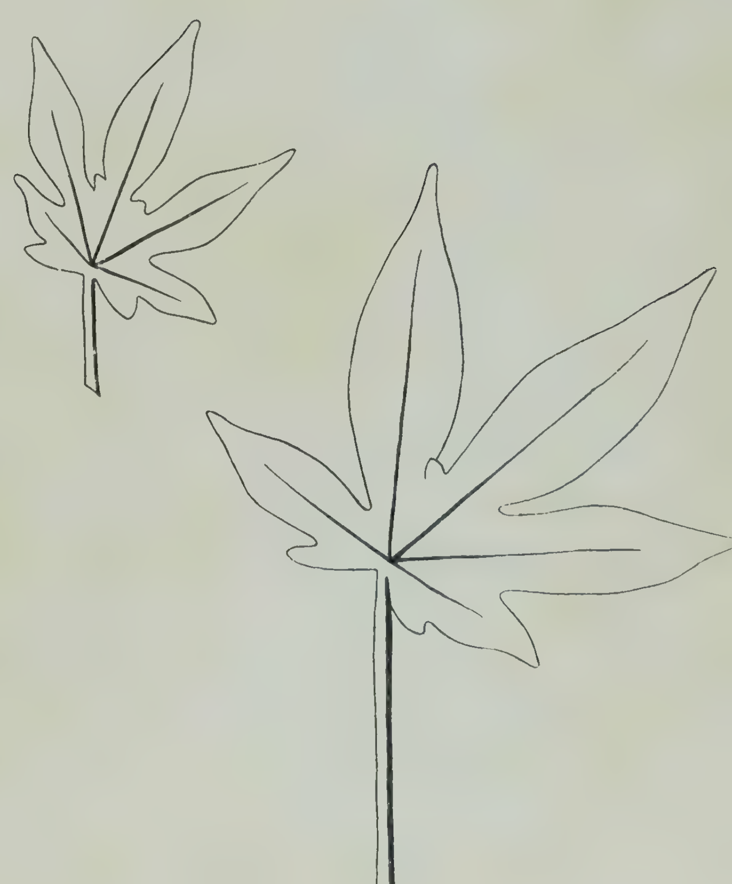

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

FIG. 11.

FIG. 12.

FIG. 13.

FIG. 14.

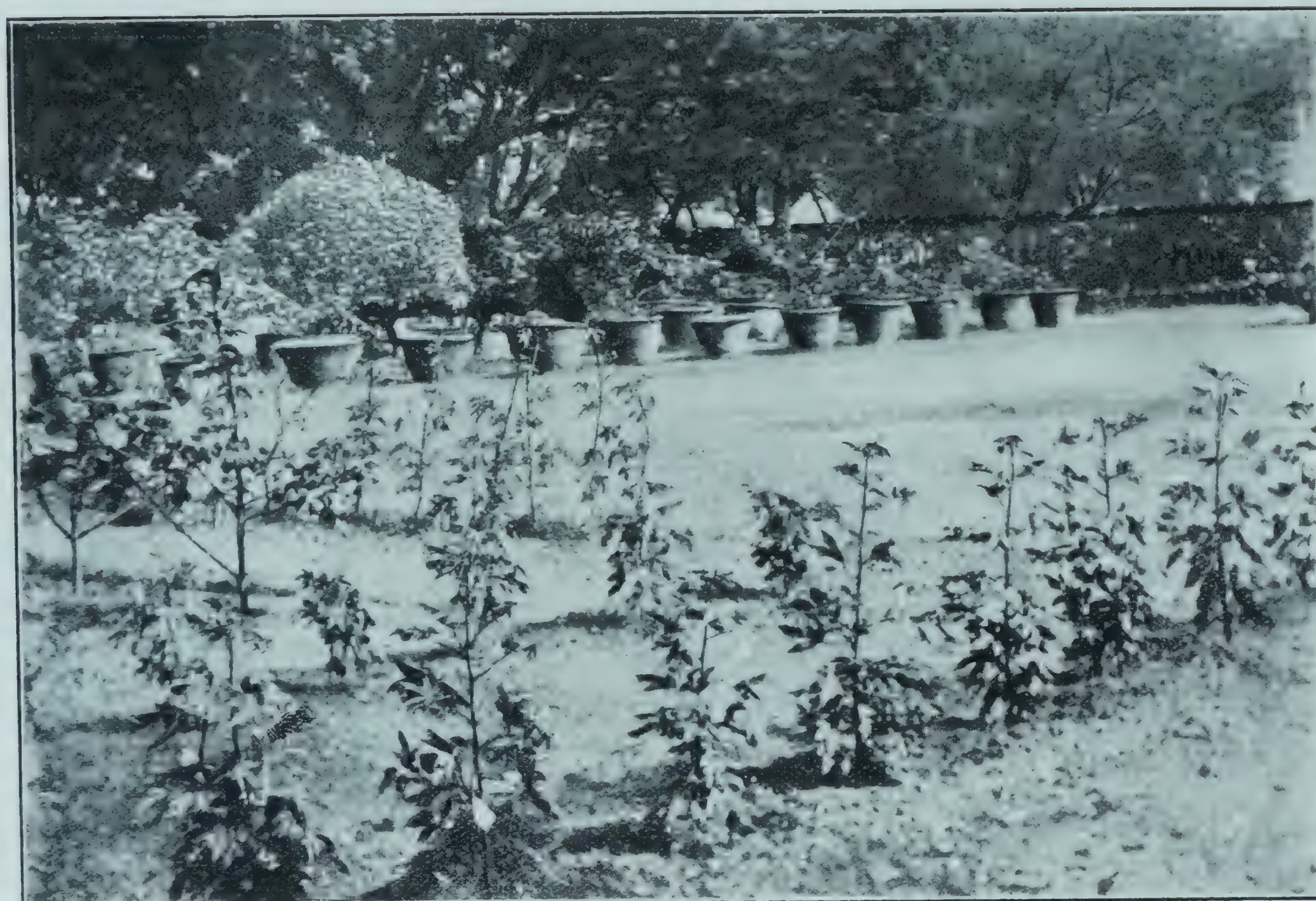

FIG. 15.

Fig. 16.

Fig. 17.

FIG. 18.

FIG. 19.

MAY, 1909.] BOTANICAL SERIES. VOL. II, No. 7.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE VARIETAL CHARACTERS OF INDIAN WHEATS

BY

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Imperial Economic Botanist

AND

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APPENDICES.

THE VARIETAL CHARACTERS OF INDIAN WHEATS.

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I. INTRODUCTORY.

During the year 1905, a collection of the wheats grown on the various experimental farms in India was made at Pusa and sown in October of that year. At the same time, a very large set of samples of the wheat actually sown by the cultivators in the districts of the Central Provinces and Bengal was, thanks to the assistance of the Directors of Agriculture and the District Officers of these Provinces, placed at our disposal. An analysis of these samples and of the crops grown in the field in many parts of India during the harvest of 1906, showed that the degree of admixture of totally different types in the wheat fields of India is very great. Further, many of the wheat plots on the experimental farms considered to be pure cultures were in reality mixed, and it became evident that the first condition of wheat improvement in India was the isolation and growth in pure culture of the types already in the country. The importance of this work cannot be overestimated. Pure cultures are necessary for all wheat experiments both for breeding purposes and also for manurial, cultivation and variety trials, for seed distribution and for milling and baking tests. Everything therefore depends on this preliminary work, and until we know with precision

the characters of the wheats now in the country, there is not much point in introducing into India wheats from other parts of the world.

The isolation of pure types from single plants and single ears was commenced at Pusa in 1905 and at Lyallpur in the following year, and has extended over three wheat-growing seasons at both stations. In addition to the work done at these places, we have collected a very large number of wheats from the various Provinces in India and have made extensive tours during the last three wheat seasons. The present paper sums up a large amount of the work so far done on the varietal characters of wheats and the influence of varying conditions on these characters, especially the effect of climate, soil and moisture on the composition and quality of the grain. Attention has also been paid to the milling and baking characters. Another subject of great interest has incidentally been investigated, namely, the frequent occurrence, in the Punjab, of natural cross-fertilisation in the field.

An exhaustive study of the wheats of the Punjab was made at the request of Mr. Renouf, Director of Agriculture of that Province, and the detailed classification of these wheats has been included as an example of the system of classification described in the following pages.

We desire to thank all the officers of the Indian Agricultural Department who have sent us specimens and, in particular, we wish to express our indebtedness to the following: to Mr. F. G. Sly, I.C.S., formerly Officiating Inspector-General of Agriculture in India, to Messrs. Renouf and Dobbs of the Punjab Agricultural Department, and to Messrs. W. H. Moreland, C.I.E., and H. M. Leake of the United Provinces Agricultural Department.

Dr. J. W. Leather, Imperial Agricultural Chemist, has assisted us by making a large number of analyses.

In the milling and baking aspect of the subject we have been fortunate enough to secure the invaluable assistance of Mr. A. E. Humphries, formerly President of the National Association of British and Irish Millers and a well-known authority on these questions.

II.

THE SPECIES AND VARIETIES OF CULTIVATED WHEATS.

The wheats of the world fall into three well-defined species :—

1. *Triticum sativum*, Lam. (= *Triticum vulgare* Vill. in erweitertem Sinne of Koernicke).[1]

2. *Triticum polonicum*, L. Polish wheat.
3. *Triticum monococcum*, L. Einkorn.

The wheats of the whole of the Continent of India, so far as we have been able to ascertain, belong to the first of these three species. These species are well marked and may be distinguished as follows :—

CONSPECTUS OF THE SPECIES.

I. The tooth (Seitenzahn) of the outer glumes blunt, rounded or absent. Pale undivided. Apical spikelet fertile.

1. *T. sativum*, Lam. Outer glumes shorter than the flowering glumes, parchment-like. Pale the same length as the flowering glume.

2. *T. polonicum*, L. Polish wheat. Outer glumes as long or longer than the flowering glumes, papery.

II. The tooth (Seitenzahn) of the outer glumes acute or acuminate, stiff, the ripe pale divided into two halves.

3. *T. monococcum*, L. Einkorn or one-grained wheat.

The first of these three species, *Triticum sativum*, Lam., is subdivided into six sub-species as follows :—

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[1] Koernicke, *Die Arten und Varietäten des Getreides*, Berlin, 1885.

TRITICUM SATIVUM LAM.

Ears with a fertile terminal spikelet and brittle or tough rachis. Outer glumes shorter than the flowering glumes with or without a blunt tooth (Seitenzahn). Pales as long as the flowering glumes, undivided.

I. Rachis brittle. Grain enclosed in the glumes when threshed.

1. *Triticum spelta*, L. Spelt. Ears bearded or beardless, long and thin, lax and somewhat square. Outer glumes very broad and truncated with a very short and blunt apex (Mittelzahn) and a somewhat undeveloped keel.

2. *Triticum dicoccum*, Schrk. Emmer. Ears nearly always bearded, dense, broader on the two-rowed side. Outer glumes sharply keeled with an acute apex.

II. Rachis tough. Grains separating from the chaff when threshed.

3. *Triticum compactum*, Host. Dwarf wheats. Ears bearded or beardless, extremely short and very compact, more or less quadrangular. Outer glumes keeled above, rounded below. Straw very short and stiff. Grains rounded.

4. *Triticum turgidum*, L. Rivet wheats. Ears bearded, large and four-sided with the spikelets closely packed on the rachis. Straw very tall, stiff, often solid. Grains large, short and thick with a blunt apex.

5. *Triticum durum*, Desf. Macaroni wheats. Ears large, dense, with long awns. Outer glumes sharply keeled to the base. Straw stiff, usually solid. Grains long, somewhat pointed, hard.

6. *Triticum vulgare*, Vill. Common wheats. Ears bearded or beardless, more or less lax (much laxer than *T. compactum*). Outer glumes keeled above, rounded below. Straw hollow, medium in length. Grains not rounded, more than twice as long as broad.

Only three of the sub-species of *Triticum sativum*, Lam., are represented in the plains, namely, *T. compactum*, Host.; *T. durum*,

Desf.; and *T. vulgare*, Vill.; and the majority of the types, including all those of agricultural importance, fall into the group known as common wheats.

Up to the sub-division of *Triticum sativum*, Lam., into six sub-species, arranged in two groups, most modern botanists are in agreement and the classification of Koernicke in the *Handbuch des Getreide baues* which we have quoted above is the one now in general use. From the point of view of the study of the numerous sorts of wheat in cultivation this classification, however, does not carry us very far. There are a very large number of distinct wheats in each of the six sub-species, and it is necessary to find some means of distinguishing these numerous forms. It is at this point that divergencies are to be met with in the literature[1] on the classification of the cultivated wheats. These differences of opinion arise from the varying degree of importance assigned by investigators to the characters used in separating the types. None of the existing schemes of classification appear to us to be beyond criticism, and we accordingly decided to make a detailed study of the characters of Indian wheats with a view of evolving a method of classification which would combine the botanical and agricultural aspects of the question.

[1] The systems of classification of wheats are dealt with by Eriksson in a paper entitled Beiträge zur Systematik des kultivierten Weizen, *Die landwirtschaftlichen Versuchs-Stationen*, Bd. 45, Heft 1 & 2, 1894.

III.

A CRITICAL STUDY OF THE VARIETAL CHARACTERS OF INDIAN WHEATS.

The influence of the environment on cultivated plants is well known and wheat is no exception to the rule. To a greater or less extent wheat is grown all over India and consequently the conditions, as regards climate, soil and moisture, under which the crop is cultivated, are very variable.

The most important conditions influencing the growth of wheat in India are :—

1. The maximum duration of the growth period in each tract.
2. The available soil moisture during that period.

The duration of the growth period is strictly limited and depends on the time when the hot weather begins in the spring. This varies with the latitude, being earlier in Bombay, the Central Provinces and Behar, a little later in the United Provinces and still later in the Punjab and North-West Frontier Province. As soon as the temperature rises above a certain point and the hot winds begin to blow, the wheat crop ripens off very quickly and dries up if not fully developed by that time. In general the crop may be said to ripen under a rapidly ascending temperature. Harvest takes place in Bombay and the Central Provinces in February, in Behar and Oudh in March and in the Punjab from the last week of April to the end of May. Only rapidly maturing wheats are of use in India either for purposes of cultivation or use in hybridisation.

Of more importance than the growth period is the variation from year to year in the available moisture. Wheat is grown on natural rainfall alone, on excessive canal irrigation as in the canal

colonies of the Punjab, on inundation water from the previous summer, on limited irrigation as in the well-irrigated tracts of the United Provinces, and finally, by means of both natural rainfall and irrigation. The great variation both in the amount and manner in which the water is supplied to the soil produces well-marked differences in the wheat crop both in the external characters such as length and strength of straw and to a greater extent in those characters connected with the quality of wheat such as the consistency of the grain and the brightness of the sample.

Accidental variations in the season have a great influence on the wheat crop in India. Among these may be mentioned excessive wet and cloudy weather just before ripening begins, leading to severe rust epidemics and exceptionally early hot spells leading to loss of soil moisture and consequent loss of maturity. Frost at the period when the grain is coming into ear is not unknown. All these vicissitudes have a marked effect on chaff colour, length and density of the ear and on straw characters, and influence the wheat plant much more than the accidents of the season do in Europe. Consequently workers on wheat improvement in India have to deal with a plant which may not reach its fullest development and may not ripen under normal conditions. It appeared, therefore, that a critical study of the various characters of wheat in India was most desirable with a view of determining how far these characters are modified by circumstances and also to decide which are most useful in India in distinguishing the varieties met with in the country. For this purpose during the last three seasons many different kinds of wheat have been grown both at Lyallpur and at Pusa. These two places in geographical position and climate represent the extreme conditions of the Indian plains. At Lyallpur, the cold weather is long and (for India) intense and the wheat is entirely grown with canal irrigation, the soil being a heavy loam. At Pusa, the cold weather is short, frost is almost unknown and wheats are grown on natural rainfall, the soil being a highly calcareous loam. At Lyallpur the air is in general very dry, whereas at Pusa in January and February the atmosphere is often damp and heavy dews and mists are frequent.

1. The presence or absence of awns.

The character used by almost all botanists from Linnaeus onwards as the first in order of importance in distinguishing varieties of wheat is the presence or absence of awns. As was to be supposed (with the exception of a few cases such as those mentioned below) the amount of bearding or its absence is constant in India and the presence or absence of awns is an important botanical character.

In our pure cultures of Punjab wheats at Lyallpur, which were started from single ears in 1906 and in other similar pure cultures at Pusa we have found that the amount of bearding and also the entirely beardless condition are not absolutely constant but that some variation takes place. Occasionally, in the so-called "beardless wheats," individuals with a certain amount of bearding may be found. In the Punjab wheat known as the Buggi of Leiah two types of ear were observed in the harvest of 1906 which only differed in one respect, one type being quite beardless, the other slightly bearded. These were sown from single ears at Lyallpur and Pusa in 1906 and again in 1907. The produce of both sets of ears was similar and each plot contained both beardless and slightly bearded ears. Often on single plants representatives of both could be found. The beardless and slightly bearded forms appear to be merely examples of fluctuating variability.

In bearded varieties a similar variation is to be met with. In the Punjab types 4 and 9 ears are often seen but slightly bearded. In pure cultures of macaroni wheats, *e.g.*, in the hard grey of Bengal *Gangajali* we have sometimes found beardless ears, due to the shedding of the awns. This is often brought about by rust attacks.

It is to the student of genetics that the variations in bearding are of greatest interest. In the study of the inheritance of awns in wheat breeding it has been found by Biffen,[1] Tschermak[2] and others that the beardless condition is a dominant character.

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[1] Biffen, *Journal of Agr. Science*, 1905, Vol. I, p. 93.
[2] *Die Zuchtung der landwirtschaftlichen Kulturpflanzen*, Bd. IV, 1907.

Saunders,[1] however, states that in some cases the F_1 generation is not always beardless, and that in the F_2 generation forms appeared exhibiting every variation between fully bearded and perfectly beardless types. In some of the crosses made at Lyallpur in 1907 between bearded and beardless parents, grown in pure culture from single ears, we found that the F_1 generation was not quite beardless.

As might be expected from the hot and dry climate of India,[2] the wheats of cultivation are usually bearded. These are preferred by the cultivators to beardless wheats, as they do not so readily shed their grain and can, therefore, be left standing at harvest time for some days after they are dead ripe—a practical point of some consequence where labour is scarce and dear at harvest time as in some districts of the Punjab. It is not likely that beardless wheats, will, on this account, be readily taken up by the ryots unless they possess obviously superior qualities to the bearded forms.

2. Chaff characters.

(*a*) *Felted and smooth chaff.*—The chaff of wheat is either felted (covered with fine velvety hairs) or smooth. In fixed types these characters are exceedingly constant even to the degree of hairiness involved. In all our crosses up to the present where one of the parents has been felted, hairy chaff has proved to be a dominant character thereby confirming the previous observations of Tschermak,[3] Biffen[4] and others.

The degree of hairiness of the Indian types varies very greatly. The Punjab macaroni wheats are very densely felted and the hairs are long, whereas the glumes in the common and dwarf wheats are generally sparsely covered with short hairs. Type 9 of the Punjab, a common wheat, resembles, however, the Punjab macaroni wheats

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1 *Report of the third International Conference on Genetics* (1906).

2 Koernicke, l. c. and Vilmorin, *Les meilleurs Blés*, Paris, 1880.

3 Tschermak, l. c.

4 Biffen, l. c.

in the length and density of the hairs on the glumes while the Behar macaroni wheats have only sparse short hairs.

Felted wheats are much commoner in the drier climate of the Punjab than in the damper wheat-growing tracts of the United Provinces, while in Bengal they are very rare. Possibly this rarity may be due to the disadvantage of hairy glumes in these moister tracts. Felted chaff holds water much more than smooth chaff, and therefore affords greater opportunities for infection by rusts. Even in the Punjab the felted wheats are often stained through the growth of mould fungi of the genus *Cladosporium* and *Alternaria*.

(*b*) *Colour of the chaff.*—The usual colour of the chaff of Indian wheats is red or white. In some cases the chaff is greyish white and varieties are met with both in the Punjab and Behar where the chaff is blackish or nearly black.

In the case of red-chaff wheats not only does the depth and tone of redness vary greatly between different types, but there is also a well-marked relation between the ripening season and the amount of redness developed in any one variety. If the weather during ripening is wet and cloudy, the red colour is not produced and real red-chaffed wheats might be then described as having white chaff. Thus, at Pusa in 1906, when the ripening period was especially unfavourable, the two Bengal macaroni wheats, which are really red-chaffed kinds, were considered by us to be white-chaffed macaronis. Even in good years, red-chaffed wheats often develop side shoots with white chaff due to premature ripening. It is only in good seasons, such as the 1906 and 1908 harvest at Lyallpur and in the present year at Pusa, that the full red colour of Indian wheats is developed. In such cases the differences in redness in the various red-chaffed types is most pronounced. While red chaff is a constant character of the variety, great care must be taken, especially in the damper wheat-growing tracts, in India in deciding this character, and it is not safe to say a wheat has white chaff unless the ears are fully and normally developed. In the Punjab one red-chaffed wheat, type 12, often shows a blackish border on the glumes. In

Bengal a form with black chaff occurs, but this black colour is only developed in good seasons.

White-chaffed wheats in India are very different from the white-chaffed varieties of Europe. Most of the Punjab white-chaffed forms have a marked reddish tinge about the glumes and awns, while the glumes have often a distinctly pink edge. A similar reddish tint is observable in the white-chaffed wheats of the United Provinces and Behar. This reddish tinge of the chaff and awns of the white-chaffed wheats combined with the poor development of colour in bad years in red-chaffed wheats makes the determination of chaff colour sometimes most difficult. One of the Punjab wheats, type 9, has greyish white chaff, but this is, no doubt, due to the thick felting on the chaff. In one case in the Punjab, the chaff is distinctly yellowish-white, but in this instance it is probable that the wheat in question was introduced into India from Australia.

Several of the wheats of India have black awns. The development of this black colour, which is seen in types 1, 2 and 9 of the Punjab, varies from year to year and only comes out well in a good year. Even in the best seasons, however, some of the "black-awned wheats" do not develop the black colour in all the ears. In 1906 at Lyallpur several ears belonging to type 1 were isolated which had perfectly white awns and only differed in this respect from ears in which the awns were deep black. The black and white-awned ears were sown singly in 1906 and again in 1907, and gave rise to absolutely similar plots. These observations agree with those of Koernicke[1] who grew the variety black-awned Emmer (*T. dicoccum* var. *atratum*) for eight years in East Prussia and seventeen years at Popplesdorf. It was found that the black colour of the awns was not always developed to the same extent and in one year was entirely absent, the variety simulating in that year the white-eared Emmer (*Triticum dicoccum* var. *majus*). In the following year, however, the awns were blacker than ever.

[1] Koernicke, l. c.

3. Grain characters.

(*a*) *Colour.*—The colour of the matured grains of the Punjab and other Indian wheats we have so far examined is either red or white. The tint of colour of both classes varies a good deal. The red wheats vary from dark brownish-red to light red, while the white wheats include yellowish and amber tints. We have experienced no difficulty in determining the colour except in cases of unripe ears where the red colour is not so well marked. As a general rule, the Indian white wheats exhibit a clearer and more marked white colour than those of colder countries.

While the various red and white wheats show different and often characteristic tints, we have not used these tints to separate the kinds on account of the influence of soil and temperature during the ripening period on the tone of colour. As will be seen in the next section, the particular tone of colour depends partly on the consistency of the grain, and since consistency varies in the same variety, both from year to year in the same locality and also in different localities in the same year, it is not safe to use tone or tint of colour as a distinguishing character. As an example of the change of tone of colour, the cultures from the same sample of Muzaffarnagar white wheat at Muzaffarnagar, Lyallpur and Pusa in 1908 may be quoted. The three samples, when placed side by side, appear quite different. The Muzaffarnagar sample is clean white, the Pusa sample amber, and the Lyallpur one intermediate.

We have been at great pains to obtain reliable evidence on the question of the change of white wheats to red when introduced into fresh localities. There are a large number of loose statements both in the Indian and European literature on this subject, and many observers consider that white wheats change into red ones when grown on certain soils. Thus, Percival[1] states:—"White wheats, however, become red in warm climates or when grown on certain soils, so that this character is of little value in a scientific scheme of classification of the different varieties." Eriksson[2] believes that white wheat

[1] Percival, *Agricultural Botany*, New Edition, 1902, p. 504.

[2] Eriksson, l.c.

becomes red and quotes Werner in support, and even goes to the length of stating that the colour of the grain is useless in distinguishing a variety. In no case, however, have we found that these supposed transformations are based on recorded scientific evidence. It is, of course, often found that when an *ordinary sample* of white wheat is tested in a new locality, the resulting grain in a few years is entirely or almost entirely red. A little consideration, however, will show that this result is no evidence of the change of a white wheat into a red one. White wheats as *ordinarily grown* in Europe and much more so in India are not pure cultures. They generally contain red wheats as impurities and, as a rule, red wheats are hardier than white sorts. Consequently, when a white wheat containing red impurities is grown in a non-white wheat locality, the struggle for existence between the red "weeds" and the white sort which at once begins, may easily result in the gradual victory of the red. In a few years, the white wheat may have disappeared entirely. The result of this alteration from a white to a red sample is of course due to the victory of the red over the white and affords no proof of a change[1] from white to red. We have so far found no evidence in the literature on wheat of a white wheat changing into a red one *when grown in pure culture from a single ear and in land where contamination of the cultures, from stray seeds left from a previous crop or from manure or irrigation water, has been guarded against.*

In seeking to obtain experimental evidence on this point in India, we were fortunate enough in 1906 to obtain a very good example. The white wheat, known as Muzaffarnagar white, has been tested in many parts of India including Oudh and Behar. In the samples grown at Pusa, Cawnpore, Lyallpur and in the Muzaffarnagar district itself, we found that the wheat was not pure but contained among other things a red wheat very similar in the ear to the true Muzaffarnagar white wheat. Pure cultures of these wheats from single ears have been grown at Lyallpur and

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1 See de Vries, *Species and Varieties—their Origin by Mutation*, 2nd Edition, page 99, and Darwin. *The Variation of Animals and Plants under Domestication*, Vol. 1, page 334.

Pusa for the last two years. No change from white to red has yet taken place, but at both stations the red form grows more vigorously than the white, and if grown in competition, there is no doubt that the red sort would win.

In many other pure cultures of both red and white wheats at Lyallpur and Pusa during the last two years, no change of white to red grain or the reverse has been noticed except in cases of natural cross-fertilisation at Lyallpur which will be discussed later on. We accordingly believe that the colour of the grain is a constant character and one of considerable value in systematic work.

In our hybridisation experiments in India we have so far found that red grain is dominant over white, a result previously obtained by many other investigators.

(*b*) *Consistency.*—A large number of observations have been made both in Europe and America on the consistency of wheat. The subject is of great importance on account of the fact that strength is often associated with a hard and translucent endosperm. The general result so far has been to indicate that consistency depends on the soil, on the available moisture and on the nutrition of the crop. Thus, in the United States, Le Clerk[1] states in the case of Durum wheats, that in humid districts and under irrigation the grain tends to become starchy, while in drier localities the grain remains flinty with a higher nitrogen content. Eriksson[2] in Sweden concludes that consistency is of no systematic value and depends more on the season than on the kind of wheat. He found that wheats brought to Sweden from Southern Europe became more and more glassy except in good years. Koernicke[3] at Poppelsdorf found there was often a change from floury grains to flinty and also the reverse, and that these changes depended both on soil and season. Fruwirth[4] in a recent discussion of the subject concludes that consistency varies with the season, soil and nutrition of the crop, and that in Europe wheats become increasingly floury from east to

[1] Le Clerk, *Yearbook of the U.S. Department of Agr.*, 1906.

[2] Eriksson, l. c.

[3] Koernicke, l. c.

[4] Fruwirth, l. c.

west and from south to north. Raum[1] at Munich found that the North German and exotic varieties became more and more flinty each year and tended to resemble the flinty Bavarian wheats. The consistency of the exotic kinds was also found to be influenced by season to a much greater extent than that of the local wheats. At Pusa, Leather has found in pot cultures of one of the Bengal macaroni wheats, that the addition of superphosphate and oil cake to the local soil alters the proportion of nitrogen to starch.

Our attention was drawn to this question during the harvest of 1906 in the Punjab. We found that in numerous cases, especially in the so-called soft white wheats, ears could be found which contained soft, hard and spotted grains. Similar observations were made in 1907 and 1908 both at Pusa and Lyallpur, and in the case of numerous samples of ears sent to us from other parts of India. We found in the case of pure culture wheats from single ears that both at Lyallpur and at Pusa soft wheats tend to become flinty. The reverse change from hard to soft is rarer, but is to be met with in macaroni wheats, *e.g.*, Punjab types 1 and 2, and the Bengal durum wheats at Pusa. A very large number of our Punjab white wheats at Lyallpur in 1908 showed hard, soft and spotted grains. There was no question of admixture, as the original selection from one ear in 1906 was made by us as well as all the subsequent sowings and harvestings and the samples were kept in safe custody. Our general experience has been that hard wheats do not change in consistency so easily as soft wheats. Both at Pusa and Lyallpur we have obtained samples differing in consistency from the same variety grown the same year in different fields or on slightly different soils. In 1908, with large cultures of selected Muzaffarnagar wheat, obtained the previous year from Muzaffarnagar, at both Pusa and Lyallpur the grain was more flinty than the original and also gave a higher nitrogen content on analysis. We conclude, therefore, with Eriksson, Koernicke and Fruwirth that consistency is useless as a varietal character and that it depends on the environment. We

[1] Raum, *Zur Kenntnis der morphologischen Veränderungen der Getreidekörner unter dem Einflusse klimatischer Verhältnisse*, Munich, 1906.

further think that it is likely that soft white wheats are only naturally produced in India in certain well-defined localities such as the western districts of the United Provinces, in the Nerbudda valley and in South Behar. Other localities, such as North Behar and Oudh and the Chenab colony of the Punjab, tend to produce more glassy wheats.

(*c*) *Shape.*—The general shape of the grain in the macaroni, dwarf and common wheats of the plains varies greatly and is characteristic of the sub-species. The macaroni wheats are, long berried, Punjab type No. 3, particularly so. Humphries[1] considers that the seeds of this type are too long to be milled in the machinery in use at present in England, and that it would pass over standard sieves with the larger impurities. The dwarf wheats have small rounded grains, especially types 7 and 4. All these dwarf wheats are unsuitable for use in England on account of the fact that the machinery used in extracting the small seeds would simultaneously take out a large proportion of the sample itself. As regards the shape of the grain in the common wheats of the Punjab, no differences of systematic value have been observed.

4. Straw characters.

(*a*) *Strength.*—In the selection of wheat varieties for cultivation, the strength of the straw is of great importance. Weak-strawed forms, however excellent in other respects, are very apt to be laid by rust, rain and wind during the ripening period, a circumstance which greatly diminishes the yield. Among the common wheats of India there are great differences in the strength of straw. Most of the wheats of the United Provinces are particularly weak as regards the straw. In general, there seems to be a connection between the strength of straw and the erectness of the ear—the stronger-strawed forms being those with erect ears at harvest time, while ears of the weaker-strawed forms bend over when ripe. Further observations on this point are desirable.

(*b*) *Structure.*—The distinctive characters of the straw of the sub-species of wheat found in the plains is well maintained. The

[1] See Appendix A.

macaroni wheats have tall straws solid in the upper portion, the other two sub-species have hollow stems. The dwarf wheats, however, have short, stiff and strong straws, while those of the common wheats are taller, thinner and on the whole weaker. No exceptions to the general rule, such as macaroni wheats with hollow stems and common wheats with solid straws, as mentioned by Koernicke,[1] have been noticed.

(*c*) *Length.*—The common wheats have straw intermediate in length between the tall stems of the macaroni wheats and the short straw of the dwarf wheats. There is considerable variation, however, in the length of straw between the various common wheats of the Indian plains.

(*d*) *Colour.*—The colour of the straw may be white, yellow or pink. The pink colour is especially well-developed in some of the Punjab dwarf wheats (types 5 and 7) and in type 19, a common wheat. It is also seen in the two Bengal durum wheats but only in good years. After exposure to the sun or after long storage the colour fades to a dirty greyish tint. It is best seen in the field just before the crop is ripe.

As regards the general straw characters, besides the main differences in the sub-species, the numerous varieties of each sub-species show well-marked straw characters. In some the straw is tall and strong and not liable to lodge and the colour may be pink. Such straw characters, however, are difficult to determine, for the length of the straw as well as its strength depends to a very large extent on the nature of the soil, the nutrition and the soil moisture. Fortunately, the character of the straw is not often needed as the sole means of distinguishing types, but if it has to be used, the wheats must be grown next to next in similar soil and under equal conditions in order that reliance can be placed on such characters. In studying the Punjab wheats, we have found it necessary in one case to separate two agricultural types mainly on their straw characters and also on earliness and lateness. In this case, however, the

[1] Koernicke, l. c.

wheats were grown in pure culture next to next under uniform conditions and were sown at the same time and at the same seed rate. This was done for two years and at each harvest the wheats differed markedly in length and strength of straw and in time of maturity, and we had no doubt that we were dealing with two different agricultural types.

5. Leaf characters.

The leaves of the three sub-species are quite distinct. The macaroni wheats have very large leaves, the dwarf wheats short and erect foliage, while the common wheats are intermediate in this respect. The leaves of the various types differ both in colour and in the degree of hairiness, but these characters were not found necessary for distinguishing the types and were not studied in any great detail. There seemed to be a distinct relationship between the water requirements of some of the sorts and the extent and character of the leaf surface, but we have so far had no opportunity of following out this point. The dwarf wheats appear to be able to mature with little moisture, while the macaroni wheats and also type No. 9 require more water to reach maturity than the other Punjab common wheats. On account of the importance of irrigation in wheat-growing in the Punjab, it appears desirable to work out in detail the water requirements of the various kinds when grown under the conditions of ordinary cultivation.

6. Earliness and lateness.

The relative earliness and lateness of varieties in India is not easy to determine with precision. It is a character which is very apt to be masked by the result of differences in soil moisture. The wheat crop in India is so exceedingly sensitive to small differences in soil moisture that a small change of level in a plot is sufficient to make a considerable difference in the time of ripening. This character must therefore only be used when the varieties are grown next to next in uniform soil and under uniform conditions. In one of our plots of macaroni wheat at Lyallpur in 1908 one-half was quite green while the other half was ripening off, the level of the unripe end

being a little lower and consequently damper than the other. Similarly at Pusa in the same year several sorts were sown in duplicate, one set on somewhat light loam, the other on heavy soil. The difference in the time of ripening of the two sets of plots was about 14 days, that on the lighter soil being of course the earlier. In our three years' study of the Punjab wheats we have always noticed certain broad distinctions in the time of ripening. The macaroni wheats and type 9 are distinctly later than the rest. Two agricultural types of common wheats were distinguished by paying attention to this point among others, but in general we have left the further details connected with this character to be settled when the types are grown on a larger scale. Several years' careful study will be required to decide the relative earliness and lateness of these types with precision. The wide differences in earliness and lateness inherent in the kinds such as are obvious in Europe are not to be seen in India as the shortness of the season renders the cultivation of really late kinds impossible. Even Canadian wheats like Red Fife only form shrivelled seed at Lyallpur while many of the European sorts do little more than come into ear before they are dried up by the hot winds. Some of the kinds, including Einkorn, do not even begin to shoot.

7. Susceptibility to rust.

We have observed the pure culture plots at Lyallpur and Pusa during the last two years with a view of finding rust resistant kinds for use in hybridisation. In dealing with this point it is necessary to realise that rust in India as elsewhere is only a general term and that there are several distinct wheat rusts in India. This aspect of the subject has been dealt with by Butler and Hayman.[1] The only season during the last three years at Lyallpur when the crop was damaged by rust was in 1907 when there was an epidemic of yellow rust (*Puccinia glumarum*, Eriks. and Henn.) and also a certain amount of black rust (*Puccinia graminis*, Pers.). All the 25 types of Punjab wheat were attacked by yellow rust, the only

[1] Butler and Hayman, *Memoirs of the Dept. of Agr. in India*, Botanical series, Vol. I, No. 2, Calcutta, 1906.

Indian wheats which were resistant being Emmer[1] (*T. dicoccum* Schrk.) In 1906 and 1908 the amount of rust at Lyallpur was slight. Further detailed observations are necessary to work out the relations between the Punjab wheats and the rusts which attack them and the work is now possible as the types have been isolated and grown in pure culture. As in other characters, observations on rust resistance are of no value when the plots are mixtures of many different kinds. Some of the Punjab types have been grown at Pusa when most of them were severely attacked by brown rust (*Puccinia triticina* Eriks.). Both at Pusa and Lyallpur we observed great differences in the amount of rust on the same variety when sown on slightly different soils. At Pusa, there is as a rule much more rust when the soil moisture is liable to give out, than there is on the heavier moisture retaining soils. The degree of susceptibility of the various kinds to the three Indian rusts is of importance in plant breeding as Biffen[2] has found in England that immunity to yellow rust is a recessive character.

8. Structure of the ear.

(*a*) *The form or shape of the ear.*—The shape of the ear of the common wheats of the plains of India does not exhibit the same range as in Europe, and it is not possible to utilise this character to the same extent as has been done at the Svalöf[3] Experiment Station in Sweden.

(*b*) *Density of the Ear.*—The density of the spikelets on the rachis has been used by many observers as a character for differentiating the various kinds. Wheats are often referred to as lax, medium or dense according to the distance between the spikelets. These terms, however, are not very definite, and we have followed von

[1] Howard, A. & G. L. C., *Jour. Agr. Science*, Vol. II, 1907, p. 278.

[2] Biffen, R. H., *Jour. of Agr. Science*, Vol. II, 1907, p. 109.

[3] Fruwirth, l. c.

Neergard[1] in expressing the density of the ear by a number (D) which gives the number of spikelets per 100 mm. of the rachis.

Most of the common wheats are very much alike as regards density. From the measurements of D in the Punjab 1908 crop they fall into two groups represented by densities of 20 or 24. This fact combined with the great variation in density produced by the conditions of growth in India has led us to reject density as a means of distinguishing the kinds in India. Differences in soil moisture and nutrition affect the length of the ear considerably, while the onset of the hot weather often cuts short the development of the later shoots, the ears of which are much shorter and denser than the earlier formed ears on the same plants. We have found that greater differences in density in ears of the same plant can be obtained than exist between different kinds of common wheat. Eriksson[2] has laid great stress on density in his classification of European wheats and in fact divides up his botanical varieties by means of this character. The conditions in India are such that his classification could not be usefully adopted.

(*c*) *Character of the spikelets and glumes.*—In one instance the shape of the spikelets and glumes has been used to help to separate two kinds very similar in most other respects. The ease with which the spikelets shed their grain is also an important character and one which is very constant for any particular kind. As a general rule in India, the beardless wheats shed their grain more readily than the bearded forms and are consequently not favourites with the ryots. Thin glumes generally go with easily shed grain while the thick glumed forms hold their grain much more strongly. An extreme case of a thick glumed wheat which holds the grain is to be seen in Indian Emmer.

The character of the keel of the outer glumes is of great importance. In macaroni wheats the keel is very pronounced right down to the base of the outer glumes, while in the dwarf and common

[1] von Neergard, Normal system för bedömande af axets morfologiska sammansättning hos vara sädesslag, *Allm. svenska Utsädesföreningens anberättelse för ar* 1887, s. 37.

[2] Eriksson, l. c. See also Fruwirth, Bd. IV, page 146.

wheats the keel is only pronounced in the upper portion and fades away or entirely disappears in the lower half. In Punjab type 9, however, the keel, although not so pronounced as in the macaroni wheats, is nevertheless distinctly represented in the lower part of the outer glume.

(*d*) *Erectness of the ear.*—The erectness of the ear is a character which we have found most useful in distinguishing in the field agricultural kinds which are very similar morphologically. In the arrangement of our Lyallpur plots all the wheats which, in the first selection in 1906, appeared to be either identical or else closely related were sown next to next. In some cases where a difference existed between two similar but not identical sorts, it was often easy to see by the position of the ears that the two kinds were different. In the one case the ears had a tendency to bend over while in the neighbouring plots the ears stood erect. Such differences in erectness were naturally accompanied by other differences in straw character and tone of colour of the chaff. It is a character which can only be used in the field and in plots which cover a certain amount of ground like that occupied by the produce of a single ear in the second season. It is not always possible to observe it in the first selection from a mixed plot.

9. Summary of botanical & field characters.

It will be convenient to deal with the above characters under two heads: (1) botanical or morphological: and (2) field or agricultural characters.

Botanical or morphological characters are those characters which remain constant with change of environment or season and which are inherited. They can be determined in the laboratory from properly developed specimens. These botanical characters are :—

1. Presence or absence of awns.
2. Felted or smooth chaff.
3. Colour of the chaff.
4. Colour of the grain.

5. Structure of the straw.
6. Character of the leaves.
7. Form or shape of the ear.
8. Character of the spikelets and glumes.

Field or agricultural characters are less conspicuous and cannot be distinguished in the laboratory or from individual plants. They can only be fully appreciated in pure cultures in the field grown side by side and under uniform conditions. The erectness of the ear, the tone of colour of the chaff and straw are field characters influenced less by season and environment than such agricultural characters as the strength and length of straw, earliness and lateness, the density of the spikelets and susceptibility to rust. All the above are characters of the greatest use and are to a very large extent inherited, but the latter group are liable to the effects of environment and season. How change of soil, moisture and locality affects them has already been dealt with and need not be repeated.

The consistency of the grain and the brightness of the sample are exceedingly variable even in the same locality, and we have not used these characters at all in separating sorts.

In considering the detailed classification of the wheats a difficulty is met with on account of the very different meanings attached to the various sub-divisions of the species. Such terms as variety, sub-variety, race, type, kind, sort are very seldom defined and where they are explained it is found that different writers use them in very different senses. The best discussion of the subject we have found is that given by Fruwirth.[1] He deals at considerable length and in detail with the development of the conception of varieties, and "Sorten" up to the present time.

We have followed Koernicke[2] as to the meaning of the term variety. By variety is understood those forms of a sub-species or

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[1] Fruwirth, *Die Zuchtung der landwirtschaftlichen Kulturpflanzen*, Bd. 1, Zweite auflage, 1905.

[2] Koernicke, l. c.

species which can be differentiated in properly developed single individuals by definite, inherited and easily distinguishable characters, such as the presence or absence of the awns, smooth or felted chaff, colour of the glumes and grains. Our varieties are therefore the botanical units of the species and sub-species and represent the lowest limit to which wheats can be divided in the laboratory with precision. Each variety, however, may comprise several agriculturally distinct types. We have divided the varieties where necessary into types by means of the field characters, such as length and strength of straw, earliness or lateness, tone of colour of chaff and straw, erectness of the ear, and susceptibility to rust. The types represent the agricultural units of a variety in a similar manner as the varieties are the botanical units of the species or sub-species. The agricultural types are just as constant as the botanical varieties, but are not so readily distinguished except in the field. To determine the types it is necessary to grow them in pure culture for several years under uniform conditions. We have in our study of the Punjab wheats carried the classification down to the type. Our types are practically synonymous with the "Sorten" of Fruwirth and Koernicke. In more than one case the same botanical variety contained valuable and almost useless types. We have found it best to distinguish the types not by one character alone but by the sum of their field characters.

As regards the system of classification in the cultivated wheats, three have been proposed—those of Koernicke,[1] Eriksson[2] and Vilmorin.[3] It has been already pointed out that the system of Eriksson depends on the density of the spikelets and is unsuitable for use in India. Vilmorin has not sufficiently distinguished between the types, while Koernicke in *Die Arten and Varietäten des Getreides*, only considers the botanical varieties. Koernicke's classification has been extended by Werner[4] in *Die Sorten und der Anbau des Getreides*, but he has only

[1] Koernicke, l. c.

[2] Eriksson, l. c.

[3] Vilmorin, l. c.

[4] Werner, *Die Sorten und der Anbau des Getreides*, Berlin, 1885.

described the " Sorten" one after the other under Koernicke's varieties, and there is nothing to show how far the names really represent different types.

We have followed Koernicke as regards the varieties using his varietal names and have extended the classification down to the types.

In the following classification we have therefore used :—

1. As varietal characters :—
   a. Presence or absence of awns.
   b. Felted or smooth chaff.
   c. Colour of chaff (red or white).
   d. Colour of grain (red or white).
2. As agricultural type characters :—
   a. Tone of colour of chaff.
   b. Erectness of ears.
   c. Characters of straw (length, strength and colour).
   d. Earliness and lateness.
   e. Susceptibility to rust.

IV.

CLASSIFICATION AND DESCRIPTION OF THE WHEATS OF THE PUNJAB.

The material from which our types were segregated consisted of 72 plots of wheat at Lyallpur (collected by the Director of Agriculture from all the districts of the province), and also a collection of the wheats grown by the cultivators of the Chenab colony. These plots were carefully searched in the field during the harvest of 1906, and all the constituents of each plot collected. These were then examined in the laboratory at Pusa and separated into botanical varieties. The same botanical variety was thus often found to occur in many plots.

The botanical varieties were sown at Lyallpur in 1906 as follows: the constituents of each variety found in the various plots were sown separately from single plants, and in 1907 these cultures were carefully examined both for vegetative characters at flowering time and also for further agricultural or field characters at harvest time. In this way it was found that in many cases the variety was made up of several types, in others there was only one type. The types were then described and the cultures repeated in 1907. In 1908, the types were finally determined in the field from a study of the comparatively large plots then available. Twenty-five different types were distinguished, the classification and description of which are given below. In many cases it was found that the types occur all over the province either in partly pure or very mixed culture under different names, and that many of the wheats cultivated in the new Chenab colonies were brought by the settlers from other parts of the province. Many of the wheats commonly grown are without doubt of a poor character and not very valuable for export pur-

poses. Others, on the other hand, including some of the rarities, are likely to be of considerable value:—

CLASSIFICATION OF THE PUNJAB WHEATS.

Triticum durum Desf. Macaroni wheats.

I. Glumes felted.

A. Glumes white, awns often black.

a. Grain white.

var. *melanopus* Al.

Type 1.

b. Grain red.

var. *africanum* Kcke.

Type 2.

II. Glumes smooth.

A. Glumes white, awns always white.

a. Grain white.

var. *leucurum* Al.

Type 3.

Triticum compactum Host. Dwarf wheats.

I. Ears bearded.

1. Glumes smooth.

A. Glumes red.

a. Grain red.

var. *erinaceum* Kcke.

Type 4.

II. Ears beardless.

1. Glumes felted.

A. Glumes white.

a. Grain white.

var. *linaza* Kcke.

Type 5.

2. Glumes smooth.
   A. Glumes white.
      a. Grain white.
         var. *Humboldti* Kcke.
            Type 7.
      b. Grain red.
         var. *Wernerianum* Kcke.
            Type 6.

TRITICUM VULGARE VILL. COMMON WHEATS.

I. Ears bearded.
1. Glumes felted.
   A. Glumes red.
      a. Grain red.
         var. *barbarossa* Al.
            Type 8.
   B. Glumes greyish white, awns black.
      a. Grain red.
         var. *fuliginosum* Al.
            Type 9.
2. Glumes smooth.
   A. Glumes red.
      a. Grain white.
         var. *erythroleucon* Kcke.

Type 10—Chaff dull light red, heads bend over when ripe, early, straw short and weak. D = 21.

Type 11—Chaff bright red, heads erect when ripe, late, straw tall and strong. D = 25.

Type 12—Chaff dull light red, with a somewhat bluish tone and with occasional blackening of the awns, chaff sometimes blackish also, heads bend over when ripe, grain easily shed, straw pink turning black on ripening, tall, of medium strength. D = 21.

      b. Grain red.

var. *ferrugineum* Al.

Type 13.

B. Glumes white.

a. Grain white.

var. *graecum* Kcke.

Type 16.

b. Grain red.

var. *erythrospermum* Kcke.

Type 14—Ears bend over when ripe, grain shed rather easily, early, straw weak, short, somewhat resistant to yellow rust. D = 23.

Type 15—Ears erect, less readily threshed than type 14, late, straw strong, tall, liable to yellow rust. D = 25.

II. Ears beardless.

1. Glumes felted.

A. Glumes red.

a. Grain white.

var. *Delfii* Kcke.

Type 17—Chaff with a bluish tinge, straw medium. D = 19.

Type 18—Chaff yellowish red, ears erect when ripe, straw stronger than 17, later in ripening. D = 26.

B. Glumes white.

a. Grain white.

var. *leucospermum* Kcke.

Type 19.

2. Glumes smooth.

A. Glumes red.

a. Grain white.

var. *alborubrum* Kcke.

Type 20—Chaff light yellowish red, ears more erect and later than in type 21, straw taller and stronger. D = 24.

Type 21—Chaff brownish red, dull, ears bend over when ripe, earlier than type 20, straw medium. D = 20.

b. Grain red.

var. *milturum* Al

Type 22—Sometimes slight bearding, chaff dark brownish red, shiny, grain dark red. D = 19.

Type 23—chaff dull yellowish red, grain easily shed, light red. D = 23.

B. Glumes white.

a. Grain white.

var. *albidum* Al.

Type 24—Spikelets blunt, outer glumes short and rounded, chaff white with a reddish border, ears bend over slightly, straw strong. D = 20.

Type 25—Spikelets pointed, outer glumes long and pointed, chaff yellowish white, shiny, ears erect, straw very strong. D = 20.

DESCRIPTION OF THE TYPES OF PUNJAB WHEAT.

Triticum durum Desf. Macaroni Wheats.

Ears flat, flowering glumes with long awns, outer glumes sharply keeled to the base, straw stiff and solid.

There are three varieties of Macaroni wheats found in the Punjab, var. *melanopus* Al. (type 1), var. *africanum* (type 2), var. *leucurum* Al. (type 3). Of these, the first is the most common and represents the so-called "Vadanak" wheat of the province. The other two were only found in very small quantities, especially type 3. Macaroni wheats on account of their large water requirements are generally only grown round wells and their cultivation is very limited. The flour is used mostly for confectionery. These wheats ripen late and are more attacked by birds than the ordinary wheats. This may be due to the stiff straw and ears on which it is possible even for heavy birds to perch and also to the fact that on account of their tall straw they range above all the other wheats. These wheats have broad long leaves smooth on the upper surface with hairs on the claws. Even when thinly sown they do not tiller much.

var. *melanopus* Al.

Type 1. Awns long, black but the black colour is lost very easily; chaff densely felted, white with a pinkish tinge, often spotted with mould fungi; grains long, amber, generally hard and flinty although occasionally mottled ones are found;[1] density varies with the rankness of growth;[2] straw tall, slender but stiff; somewhat liable to rust; ripens late.

This is the common macaroni of the Punjab and was found in the Wadanak of Zira, Wadanak of Sialkot, Wadanak of Batala, Wadanak Kalchingari of Montgomery, Wadanak of Amritsar, Dagar of P. D. Khan, Dagar of Wazirabad, Dagar of Shahpur, Pamman of Ferozepore, Dagar of Muzaffargarh, Dagar of Multan, Dagar of Montgomery and in the Wadanaks of Lyallpur, Ferozepore and Amritsar and the Palestine of Lahore.

var. *africanum* Kcke.

Type 2. Similar in most respects to type 1 but the ears taper to a point and are slightly longer; grain very dark red, hard on the whole, with a very few mottled grains; length of ear 84 mm.;[3] D = 28. This type is more liable to rust than type 1.

Type 2 was only met with as an impurity in Wadanak Kalchingari of Montgomery.

var. *leucurum* Al.

Type 3. Awns long, white with a reddish tinge; chaff smooth, shiny, white with a pinkish tinge due to the veins on the glumes being red; grain very long and thin, white, much lighter in colour than type 1, generally very hard and translucent, hardly a mottled

1 The descriptions of the consistency refer to the samples obtained in the harvest of 1908 when the types were grown in small plots next to each other.

2 Both the length of ear and the density vary very much in type 1. At first it seemed possible that there might be two types differing only in density but from the single ear culture we were unable to isolate two strains constant as regards density.

3 Length of ear & D were both measured in specimens from the harvest of 1908 and are the average of 20 typical ears. As explained in the earlier pages no great stress can be laid on these measurements. They are merely given as an indication of the value of these quantities.

grain to be found; length of ear 75 mm.; D = 22; straw good; ripens late; not so liable to rust as type 1.

Type 3 was only found as an impurity in the Wadanak of Lyallpur in very small quantity. The grains of this wheat are so long that in cleaning prior to grinding they would pass over standard sieves with the large impurities.

Triticum compactum Host.—Dwarf wheats.

Ears exceedingly dense and short, rarely over 5 cms. long, outer glumes keeled in the upper half and rounded in the lower half, straw very short and stiff, grains rounded.

There are four varieties of dwarf wheats grown in the Punjab. These wheats are drought-resisting and are generally grown on inundation moisture with little rain. They are also said to be good yielders and type 7 has a good reputation for bread making. Owing to the smallness of their grain they can however only be used for indigenous consumption and they are therefore being gradually replaced by common wheats. They agree with the common wheats in time of ripening and showed themselves exceedingly susceptible to early rust, *P. triticina* Eriks, when grown at Pusa, in fact they were almost destroyed by it. They are, however, fairly resistant to yellow rust. The ears are short and erect, the straw stiff, short (generally about 3′ 6″ or 4′), hollow throughout as in common wheats but much stouter.

Humphries[1] remarks that "types 4 and 7 are extraordinarily small in the berry, so small that millers would hesitate to buy them if they contained any small seeds because the machinery used for extracting the small seeds would take out simultaneously a very large proportion of the wheat berries themselves."

var. *erinaceum* Kcke.

Type 4. Ears bearded with short bristly spreading awns very irregular in length, awns red; chaff smooth and dark red; grain very small, round, rather a light dirty red in colour, very difficult to distinguish from a dark amber, hard on the whole with a few soft

[1] See Appendix A.

grains; ear length 50 mm.; D = 38; straw shows no pink colour.

To this type belongs the Makkhi of Chiniot.

var. *linaza* Kcke.

Type 5. Ears beardless; chaff felted with short hairs, white with a pinkish tinge due to the pink colour of the edges and veins of the glumes; grain round, small but larger than in type 4, amber coloured, hard on the whole with a few soft and mottled grains; ear length 49 mm.; D = 38; straw pinkish, turning black or greyish pink on ripening.

This type was only met with in small quantity in the Makkawali of Dera Ghazi Khan.

var. *Wernerianum* Kcke.

Type 6. Ears beardless, but with occasional very slight bearding; chaff smooth, white with a pinkish tinge; grain round, about the same size as in type 5, a clean light red, all soft; ear length 44 mm; D = 39; straw has no pink colour.

This type was only found in small quantity in the Makini of Multan.

var. *Humboldti* Kcke.

Type 7. Ears beardless; chaff smooth, white with a pinkish tinge; grain round, about the same size as in type 5 but possibly a little smaller, amber coloured, consistency very variable, hard, soft and mottled grains found in about equal proportions; ear length 45 mm.; D = 41; straw pinkish, turning black on ripening.

This is the common dwarf wheat of the Punjab and was found in the Rodi of Shahpur, Rangrih or Ghiali of Kangra, Makini of Multan, Daudi of Muzaffargarh, Daudan of Multan, Makkawali of D. G. Khan and in Daudi of Multan.

Mr. A. C. Dobbs, of Lyallpur, found that this wheat was grown at Rawalpindi and that it was considered in that district as the best for bread-making.

TRITICUM VULGARE VILL.—COMMON WHEATS.

Eighteen of the 25 types of wheat found in the Punjab belong to this species and among them are found the wheats most commonly

grown. These 18 types belong to 11 botanical varieties and are equally divided into bearded and beardless, there being 9 types belonging to each class. Among the 18 varieties only 5 are felted but among these felted types are to be found some of the best wheats of the Punjab. The range in quality is very various, type 9, one of best being a good wheat fit for export, whereas some have a most inferior grain hardly worth growing for local consumption.

var. *barbarossa* Al.

Type 8. Ears bearded; awns red; chaff felted with short, rather sparse hairs, yellowish red; grain dark red, consistency variable, hard, soft and mottled grains found in about equal proportions; ear length 78 mm.; D = 24; straw good; ears erect and rather slender.

This type was found in the Lal Kasar-wali of Lyallpur in very small quantity.

var. *fuliginosum* Al.

Type 9. Ears bearded; awns stiff, stout, rather short, black but lose their colour very easily; glumes sharply keeled to the base; chaff densely felted with long hairs, the felting resembles very closely that found on the macaronis, chaff greyish white or yellowish white, pink at the edges, generally with black spots of *Cladosporium;* grain very dark red, on the whole hard with a few mottled grains, the shape resembling that of a common wheat; ear quadratic in section, somewhat club-shaped at the top, somewhat compact; ear length variable about 70 mm. on the average; D = 25; straw stiff, stout, hollow throughout; ears very erect.

This type was found in the Lal of Batala, Ratti of Montgomery and in the Lal Kale Kasar-wali of Lyallpur, it was also found in small quantity in the Lal Desi of Jhelum, Lal of Delhi, Pamman of Ferozepore, Dagar of Multan, Kunjhari of Muzaffargarh.

This wheat is one of the most interesting types found in the Punjab for although it must be classed as a common wheat, it appears to possess many of the characters of the macaronis. The felting resembles very closely that of the macaroni wheats and is quite different to that found on the other felted common wheats or on the felted dwarf wheat. The shape of the glumes with the keeling continued sharply to the base resembles that of macaronis. The hollow straw and the shape of the grain are, however, those of a common wheat. The shape of the ear with its compact sometimes club-shaped top, the stoutness of the straw and the stiff awns remind one of the dwarf wheats and it seems quite possible that this wheat, which is unique in India, may have arisen from a natural cross between a dwarf and macaroni wheat. This supposition is supported by the fact that we have found a dwarf wheat to be the female parent in some of the natural crosses found by us and described in the last part of this paper. At flowering time this wheat (type 9) appears to shed a vast amount of pollen and probably gives rise in this way to further natural crosses (see p. 61). It is interesting to note that this wheat is marked by Humphries as being the best of the 25 Punjab types submitted to him.

var. *erythroleucon* Kcke.

Type 10. Ears bearded; awns red; chaff smooth, dull light red; grain amber coloured, liable to sprout in the ear, consistency variable, hard, soft and mottled grains found in equal proportions; length of ear 82 mm.; D = 21; straw short and weak, ears bend over when ripe; early.

This type was found in the Safed of Moga, Mundi of Ludhiana, Jogia of Karnal.

Type 11. Ears bearded; awns red; chaff smooth, a more intense and brighter red than in type 10; grain amber coloured, liable to sprout in the ear, consistency variable but with a majority of soft grains; ears squarer and denser than in type 10, ear length 76 mm.; D = 25; straw tall and strong, ears stand erect; later than type 10.

This type was found in the Safed of Amritsar, Sohan of Chiniot, Kunjhari of D. G. Khan, Daudi of Lyallpur, and in the Jogia of Karnal.

Type 12.[1] Ears bearded; awns red with occasional blackening; chaff smooth, dull light red with a somewhat bluish tone, occasional blackening on the chaff; grain amber coloured, hard on the whole; ear length 86 mm.; D = 21; straw intermediate in strength between that of types 10 & 11, pink, turning black on ripening, tall; ears bend over when ripe; early; grain easily shed.

This type was found in the Rangrih of Palampur.

var. *ferrugineum* Al.

Type 13. Ears bearded; awns red; chaff smooth, shiny, yellowish or brownish red; grain red, intermediate in colour between the dark and light red grained types, rather small, consistency variable, about two-thirds being hard; ear length 96 mm.; D = 18; straw medium; ears fairly erect; rather late.

This type was found in the Lal Kasar-wali of Lyallpur. The hard red of Gujar Khan also belongs to this type, but ripened a little later than the Lal Kasar-wali. This difference may easily disappear after the hard red of Gujar Khan is acclimatised at Lyallpur.

var. *erythrospermum* Kcke.

Type 14. Ears bearded; awns pinkish yellow; chaff smooth, white with a reddish tinge when ripe; grain light red, hard and soft grains in about equal proportions; ear length 80 mm. D = 23; straw weak and short; ears bend over when ripe; early fairly rust-resistant; sheds its grain more easily than type 15.

This type was found in the Lal of Karnal, Lal of Sialkot, Lal of Attock, Lal Safed of Sirsa, Lal of Zira, Kasalu or Surkh of Ferozepore, Ratti or Lal of P. D. Khan, Lal of Ludhiana, Desi Surkh of Jullunder, Lal Desi of Jhelum, Lal of Rawalpindi, La of Delhi, Kunjhari of Muzaffargarh.

[1] We have found some difficulty in describing the differences between these three types (10, 11 and 12): they are best seen in the field.

Type 15. Ears bearded; awns pinkish yellow; chaff smooth, white with a reddish tinge when ripe; grain light red, consistency variable but the majority are soft grains; ear length 80 mm.; D = 25; straw tall and strong; ears erect when ripe; late; susceptible to rust; grains less easily shed than in type 14.

This type was found in the Ratti or Lal of P. D. Khan, Watni of Shahpur, Kunjhari of Multan.

Types 14 and 15 form the common red wheat of the Punjab. A glance at the names of the varieties will show that they are cultivated all over the province. They are very similar to, if not identical with, the common red wheats cultivated in the United Provinces. These two types are absolutely identical in the laboratory but quite different in the field.

var. *graecum* Kcke.

Type 16. Ears bearded; awns rather pinkish yellow; chaff smooth, white with pink edges and veins; grain white, rather small, on the whole soft but with some hard and mottled grains; ear length 78 mm.; D = 23; straw fairly strong.

This type was found in the Ghoni of Lahore, Safed of Ludhiana, Safed of Rohtak, Safed of Batala, Daudkhani of Dāsuya, Daudkhani of Delhi, Pori of Montgomery and in the Safed Kasar-wali of Lyallpur.

var. *Delfii* Kcke.

Type 17. Ear beardless; chaff felted with short, rather sparse hairs, red with a bluish tinge; grain amber coloured, consistency variable, hard, soft and mottled grains present in equal proportions; ear length 94 mm.; D = 19; straw medium.

This type was found in the Rodi of Attock, Ghoni of Gujrat, Ghoni of Sialkot, Khoni of Jhelum, Ghoni of Chiniot, Ghoni of Amritsar, Khoni of Batala, Mundli of Karnal, Mundli of Ludhiana, Safed of Lahore, Kanku of Palampur, Jhakrehun of Palampur, Safed Brij Sondha of Rohtak and in small quantity in the Rodi

of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khan, Suthra of Multan.

This is a very common wheat in the Punjab.

Type 18. Ears beardless; chaff felted with short, rather sparse hairs, yellowish red; grain amber coloured, consistency variable, but the majority of the grains are soft; ear length 72 mm.; D = 26; ears squarer and denser than in type 17; straw stronger than in type 17; later in ripening.

This type was found in the Rodi of Muzaffargarh, Ghoni Lal, Ratti of Muzaffargarh, Desi of D. G. Khan, Suthra of Multan and in small quantity in the Ghoni of Chiniot, Ghoni of Amritsar, Jhakrehun of Palampur.

var. *leucospermum* Kcke.

Type 19. Ears beardless but occasional slight bearding met with; chaff felted with some short somewhat sparse hairs, white with pink veins or edges to the glumes; grain whiter than in 17, 18 and 21 but darker than 16; consistency variable but about three-quarters of the grains soft; ear length 74 mm.; D = 24; straw strong, pinkish, turning black on ripening.

This type was found only in very small quantity in the Buggi of Leiah at Lyallpur.

var. *alborubrum* Kcke.

Type 20. Ears beardless with occasional very slight bearding; chaff smooth, light yellowish red; grain amber coloured, rather large, consistency variable but about two-thirds of the grains soft; ear length 78 mm.; D = 24; straw taller and stronger, ears more erect and later in ripening than type 21; grain very easily shed.

This type was only found in the Ghoni of Amritsar.

Type 21. Ears beardless, with occasional very slight bearding; chaff smooth, brownish red, dull; grain amber coloured but somewhat whiter than 17, 18 and 20, consistency variable, about an equal amount of hard, soft and mottled grains; ear length 90 mm.;

D = 20; straw medium; ears bend over when ripe; earlier than type 20; grain very easily shed.

This type was found in the Kanku of Palampur and in small quantity in the Rodi of Attock, Ghoni of Gujrat, Ghoni of Sialkot, Khoni of Jhelum, Khoni of Batala, Mundli of Karnal, Mundli of Jullunder, Mundli of Ludhiana, Jhakrehun of Palampur, Ratti of Muzaffargarh, Kunjhari of Muzaffargarh, Kunjhari of Multan, Safed Ghoni and Ghoni Lal.

var. *milturum* Al.

Type 22. Ears beardless sometimes slightly bearded; chaff smooth, shining, dark brownish red; grain very dark red, consistency variable but on the whole the sample is hard; ear length 94 mm.; D = 19; straw medium but rather better than in type 23.

This type was found in small quantity in the Ghoni of Sialkot and in Safed Ghoni.

Type 23. Ears beardless; chaff smooth, dull, yellowish red; grain very light red, somewhat small, entirely soft; ear length 81 mm.; D = 23; straw medium.

This type was only found in the Ratti of Muzaffargarh.

var. *albidum* Al.

Type 24. Ears beardless; spikelets blunt; outer glumes short and rounded, chaff smooth, white with a reddish border; grain yellowish white, resembles 19, rather large, consistency variable but on the whole the sample is soft; ear length 93 mm.; D = 20; straw strong; ears bend over slightly.

This type was found in the Koni of Chakwal, Kunj of Muzaffargarh, Buggi of Leiah and Safed Ghoni.

Type 25. Ears beardless, often slightly bearded; spikelets pointed, outer glumes long and pointed: chaff smooth, yellowish white, shiny, with very slight reddish border; grain larger than in any other of the types of common wheat in the Punjab, greyish white of a different tone of colour to any of the other white wheats,

on the whole soft; ear length 100 mm.; D = 20; straw very strong; ears erect.

This type was found in Buggi of Leiah and Safed Ghoni.

These two types, 24 and 25, differ in appearance so much from all the other wheats of the Punjab and bear such a strong resemblance to the Australian wheats introduced into the province that we cannot help suspecting that they originally came from Australia.

V.

THE QUALITY OF INDIAN WHEAT.

There are two points to be taken into account when considering the quality of the wheats produced in a country like India. In order of importance they are, firstly, the needs of the local market and, secondly, the requirements of the export trade. It is commonly supposed that the classes of wheat best suited to the Indian and European markets are quite distinct. We shall endeavour to show in this section that such an idea is erroneous and that the wheats in greatest demand for local consumption and those preferred by the English millers are of the same general class, namely, hard and flinty wheats. We propose to put forward evidence, to show that the present cultivation of weak soft wheats like Muzaffarnagar white for export is a mistake and has been the means of lowering the status of Indian wheat in the English market and consequently has entailed the loss of large sums of money to the Indian producer.

The quality of a wheat for bread-making purposes depends chiefly on the consistency, colour, composition and milling characters of the grain and on the colour and baking value of the resulting flour. These matters will be dealt with in order.

1. Consistency.

In a previous section (p. 14) the subject of the consistency of the wheat grain from the systematic point of view has been considered and it has been shown that for purposes of classification this character varies to too great an extent with the environment to be of any value. From the milling point of view the consistency of the wheat grain is of the greatest importance and to some extent

determines the market value of a wheat. Millers like wheats of uniform consistency and on this account definite grades are maintained in the United States and Canada, and an inspection system has been built up for the purpose of maintaining these grades. As far as possible, hard and soft wheats are kept distinct and fall into the various hard or soft grades. It is in the conditioning or in the adjustment of moisture prior to grinding that the miller finds it an advantage to handle hard and soft wheats separately and where a mixture of hard and soft leads to trouble and loss. Consequently it is an advantage to export wheats uniform in consistency. Unfortunately, however, in India, wheats do not always come true to texture and we have found in the Chenab Colony of the Punjab, where wheat is grown under excessive Canal irrigation, there is a tendency towards the production of mottled grains—hard and soft in places—and to an unevenness in consistency. As has been pointed out above (p. 14), new wheats introduced into a district tend to develop the same consistency as that of the country wheats. Thus at Pusa, wheats tend to become hard and flinty. In some parts of the United Provinces, for example the Muzaffarnagar district, uniform soft grades appear to be developed.

To bring out this point a pure sample of Muzaffarnagar white was grown in 1908 in three localities—at Lyallpur in the Punjab, at Muzaffarnagar in the United Provinces and at Pusa in North Behar. In consistency, the resulting harvest was quite distinct. At Muzaffarnagar, the sample was uniformly soft white, at Lyallpur there was a fair proportion of flinty and semi-flinty grains, while the general tint was a duller white. At Pusa, the colour was amber and the majority of the grains were hard or semi-hard. As will be seen below, both the composition and baking values of these three samples were notably different, and the Pusa grown specimen was considerably the best. It is one of the future problems in Indian wheat investigations to see how far consistency can be regulated by cultivation and irrigation and in what tracts wheats uniform in consistency can be produced.

2. Colour.

The change, now almost complete in Great Britain, from the old system of grinding wheat under mill-stones to that of the modern roller mill has led to quite different views on the part of millers as to the importance of the colour of the grain. Under mill-stones more of the skin of the grain found its way into the flour and consequently red wheats did not yield flour of such good colour as white wheats.[1] With roller mills, however, the separation of the skin is almost complete and the disadvantages of red wheats no longer exist to any appreciable extent. That this is so is evident when it is remembered that Canadian Fife wheat which is one of the strongest wheats exported to England is a hard red wheat but realises prices about the highest in the market.

While it is not possible to judge the milling value of a wheat from the colour, yet it is safe to state that, as a rule, the hard wheats with a somewhat dark tint have the highest nitrogen content and give the best results in the bakehouse. Very light red and white wheats often give weak flours.

3. Composition.

Although a great deal of work has been done on the chemical composition of wheat and of wheat flour, yet no accurate relation has hitherto been found between the chemical composition and the breadmaking value of wheat. The only determination of any value is the nitrogen content which is usually determined by Kjeldahl's method and which, when multiplied by the factor 5·7, gives the percentage of proteids. Hall[2] found that *as a rule* the higher the nitrogen content the stronger the flour, but there are exceptions as some wheats high in nitrogen give very weak flours.

The range in total nitrogen and proteid content in wheat is very great. Thus Soule and Vanatter[3] in America give 8·1 & 13·6 as the limits of the proteid percentage in the American wheats

1 Maurizio, *Getreide. Mehl und Brot*, Berlin, 1903, p. 112.

2 Hall, A. D., *Journal of the Board of Agriculture* (England), Vol. XI, No. 6.

3 Soule and Vanatter, *Bull. IV, Agr. Expt. Sta. Tennessee*, 1903.

investigated by them. Far higher values, however, can be obtained, some of the stronger wheats of Hungary, Roumania and South Russia often containing 20 per cent. or more of gluten.

According to Fruwirth,[1] climate in Europe has a considerable effect on the composition of wheat. "Dryness and poverty of soil clearly increase the gluten content. Besides this it must be remembered that according to Wollny high summer temperature and low rainfall in Hungary, Roumania and South Russia favour nitrogen content and flintiness; cooler damper climates, on the other hand, favour starch production and flouriness. In agreement with this the nitrogen content of wheat in Europe in general diminishes from South to North and from East to West. Thus the gluten content in South Russia, Roumania and Turkey is 20 per cent. or over, in Germany and France 10 to 15 per cent., and in England seldom more than 10 per cent."

Tschermak[2] quotes several cases of change of composition when European wheats were removed from one country to another.

During the season 1907-08 in India we obtained results with Muzaffarnagar white similar to those discussed by Tschermak. Samples of this wheat grown at Lyallpur, Muzaffarnagar and Pusa gave very different results on analysis and also differed considerably in bread-making value.

Composition and baking value of Muzaffarnagar wheat grown at three stations in 1908.—

	% Nitrogen. (Leather).	Order in Baking value (Humphries).
1. Grown at Pusa	1·86	Fifth.
2. Grown at Lyallpur ..	1·50	Eighth.
3. Grown at Muzaffarnagar ...	1·38	Ninth.

The nitrogen content of the 25 Punjab types has been determined on the 1908 crop by Leather as follows :—

[1] Fruwirth, l. c.

[2] Tschermak, l. c.

Nitrogen content of Punjab wheats.

Type No.	1	2	3	4	5	6	7	8	9
Percentage of Nitrogen ...	1·75	2·61	2· 2	2·14	1·78	1·62	1·71	1 52	2·01

Type No.	10	11	12	13	14	15	16	17	18
Percentage of Nitrogen ...	1·40	1·34	1·50	1·57	1·37	1·43	1·39	1·42	1·39

Type No.	19	20	21	22	23	24	25
Percentage of Nitrogen ...	1·35	1·43	1·45	1·38	1·35	1·37	1·62

It will be seen that with one exception the common wheats, Types 8 to 25, all give nitrogen values below 2 per cent. and are therefore low in gluten. The macaroni wheats, types 1 to 3, and the dwarf wheats, types 4 to 7, on the whole, are distinctly higher in nitrogen than the common wheats.

4. Milling and baking tests.

A considerable amount of information as to the probable usefulness of a wheat can be given by an expert miller who is accustomed to buy wheats on hand samples and to grind them into flour. Accordingly, the types of Punjab wheat were submitted to Mr. Humphries of Weybridge and his report is given in Appendix A. From this it will be seen that types 8 and 9, both red wheats, were considered to be the best. A still more reliable opinion, however, can be obtained from an actual milling and baking test, if conducted by an expert provided with a suitable mill and baking facilities. This was done for us this year by Mr. Humphries with ten samples, each about 60 lbs. in weight, from various parts of the Indo-Gangetic plain.

Six of these wheats were obtained from Lyallpur, one from Gujar Khan, one from Muzaffarnagar, and two from Pusa :—

Description and composition of ten samples of Indian wheat tested in England in 1908.

No.	Name.	Grown at	Character of grain.	Percentage of Nitrogen (Leather).
1	Pusa No. 6	Pusa ...	Hard white	2·52
2	Lal Kasarwala.	Lyallpur ...	Hard white .	Not determined.
3	Punjab type 9	Lyallpur	Hard red	2·01
4	Gujar Khan .	Gujar Khan ...	Hard red ...	1·76
5	Muzaffarnag a r white.	Pusa ..	Semi-soft white	1·86
6	Punjab type 16.	Lyallpur .	Soft white ...	1·39
7	Punjab type 14.	Lyallpur ...	Soft red ...	1·37
8	Muzaffarnag a r white.	Lyallpur	Soft white	1·45
9	Muzaffarnag a r white.	Mazaffarnagar	Soft white ..	1·34
10	Australian 27...	Lyallpur ...	Soft white ...	Not determined.

Numbers 1, 3, 5, 6, 7 and 8 were pure cultures grown by us at Pusa and Lyallpur. Nos. 2, 4, 9 and 10 were obtained in ear from cultivators' fields, all ears not true to type being picked out before threshing.

The report on the milling and baking qualities of these wheats is given below :—

REPORT BY A. E. HUMPHRIES, ESQ., PAST PRESIDENT OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS AND CHAIRMAN OF THE HOME-GROWN WHEAT COMMITTEE OF THE INCORPORATED NATIONAL ASSOCIATION OF BRITISH AND IRISH MILLERS ON THE TEN SAMPLES OF INDIAN WHEAT SENT FROM PUSA IN 1908.

I duly received, *viâ* Calcutta or Kurrachee, the ten sample lots of various wheats grown in India, upon which the Agricultural Department of the Indian Government wished me to report, and in accordance with the arrangement arrived at with you, I have cleaned, conditioned, milled and baked each lot separately and have done each operation in duplicate.

I have regarded the whole matter from the standpoint of a British miller and am accustomed to buy Indian wheats on a commercial basis for the manufacture of flour to be used in England.

The methods of milling and baking followed are those which I have used in making a great number of similar tests for the Home-grown Wheat Committee of the National Association of British and Irish Millers.

The ten samples were designated as follows :—

Red wheats.—Gujar Khan.
Punjab Type 9.
Punjab Type 14.

White wheats.—Pusa 6 grown at Pusa.
Lal Kasar Wala.
Muzaffarnagar grown at Lyallpur.
,, ,, ,, Muzaffarnagar.
,, ,, ,, Pusa.
Australian 27 Lyallpur.
Punjab Type 16.

I do not think that the colour of the husk need be or is likely to be of great importance. British millers are guided in their preferences principally by the quality and quantity of flour which Indian wheats would yield, but if on other points a red wheat and a white wheat were equal, the preference would be given to the white wheat.

Each of the ten samples was noteworthily free from dirt and extraneous matter. The arrangements arrived at by the joint action of shippers, the leading British Corn Trade Association and the Association of British and Irish Millers have brought about a great improvement on this point in the recent shipments of Indian wheat, and if it be possible to ship wheat as "clean" as the ten samples I have received, the relative value of Indian wheats would be still further enhanced.

As part of the process of cleaning wheat by washing, and to prevent as far as possible the pulverizing of the husk in grinding and so secure a better separation of husk from kernel, it is the custom of British Millers to "condition" their wheats.

The most important point in the conditioning is the adjustment of the moistures immediately prior to grinding, so that wheats with

high moistures would be dried and wheats with low natural moistures would be damped. Of course, this means that practically all Indian wheats would be damped and that the driest would be worth more to the miller than those with higher moistures. Incidentally, I should like to mention the belief entertained here that some parcels of Indian wheat are artificially damped before shipment. Any such action is unwise from the Indian point of view. It is risky as regards the effect on quality, it seems silly to pay railway and ocean freight on water, and any gain so obtained on the first few transactions would be much more than lost in the long run, because all British Millers of good standing know quite well the moistures of the wheats they receive, that point enters into their calculations as to the relative values of wheats, and they are likely to base their calculations to the detriment of sellers on the highest percentage of water the wheats they buy will contain.

The ten samples were all in the best of condition on arrival.

When water is added in the process of cleaning and conditioning, it affects the kernel as well as the husk, and all varieties of wheat are not affected alike. Some remain "free grinding," that is to say, the kernel, when pulverized, makes lively granular flour which can be separated from husk with a minimum of trouble to the miller; others become "woolly" in texture, the flour is less granular and the separations in the mill are made with difficulty.

The ten samples show a striking difference in this respect. For free grinding Pusa 6 is very good indeed, Australian 27 poor. The Muzaffarnagars are also poor in this respect, and of the three the one grown at Lyallpur is the worst. The five sorts not specifically mentioned in this connection are good as regards this characteristic.

There are very great differences in the hue of the flours from the ten samples. The three Muzaffarnagars all yield flour very white in hue. Of the three, that grown at Muzaffarnagar is the whitest, that grown at Pusa is substantially the same, whilst the Lyallpur lot of this variety has a comparatively dingy hue. I think this is associated with the "woolliness" I have mentioned, because to get a commercially complete separation of husk from

kernel more force in grinding has to be used and more of the husk accordingly gets pulverised in the grinding. The Australian 27 yields also a white flour. Punjab Type 9 yields a bright but very yellow flour. Gujar Khan one that is yellow in slightly lesser degree. Pusa 6 is as regards colour in a class by itself, for its very lively granular flour is neither white of chalky hue nor yellow, but a greyish white, which I associate with Canadian Fife wheat. Of the other three sorts not specifically mentioned in this paragraph, Punjab Type 16 yields flour of very good appearance as regards hue, medium between the chalky white of the Muzaffarnagar and the yellows of the Punjab Type 9 and Gujar Khan. A large number of British millers use artificial bleaching. In their hands the two last named would give good results as to colour. In some parts of England and in Ireland flour of chalky white hue is required, and for those purposes the sorts yielding such flour might be preferred, but my own preference as to colour would be Pusa 6 or Lal Kasar Wala, and this, I think, would be the verdict of most English millers.

There are great differences between the ten as regards strength, by which I mean the capacity for making large shapely loaves. On this point Pusa 6 is pre-eminent. The loaves are not only larger, but whereas those from all the other flours have the appearance typical of Indian varieties, those from Pusa 6 have a quite different and a superior crust and general appearance. Gujar Khan, Punjab Type 9 and Lal Kasar Wala are not far behind so far as size of loaf is concerned. Of the three Muzaffarnagars, the Pusa lot is distinctly the best, the Muzaffarnagar distinctly the worst, the Lyallpur lot occupies the middle position. The Punjab Types 14 and 16 and Australian 27, are only poor on this point.

As regards the stability of dough, in baking all are good. Pusa 6 is the nearest approach to the toughness which is associated with Canadian or American Spring Wheats, but that is not to be compared with those sorts, nor should I expect to find any wheats behaving in that way unless with great summer heat a high summer rainfall be associated.

In summarizing the foregoing, I unhesitatingly express the opinion that Pusa 6 is the best, and I can quite as unhesitatingly say, I do not like Australian 27 or Muzaffarnagar grown at Muzaffarnagar. There is a growing inclination amongst grain merchants to mix their wheats so as to reduce the number of grades in which they deal. No particular harm would be done if they mixed as follows :—

A. Muzaffarnagar grown at Muzaffarnagar.
,, ,, ,, Lyallpur.
,, ,, ,, Pusa.
27 Australian.

B. Lal Kasar Wala.
Punjab Type 16.

C. Punjab Type 9.
Gujar Khan.

Punjab Type 14 might be grouped with C, but would be better handled separately. Pusa 6 might be grouped with B, but would make most money if sold by itself, on its own sample or reputation. Group A should not be mixed with either B or C, nor should any individual of the group A be mixed with any member of the group B or C. If group B were mixed with group C, no particular harm would be done, but they are better apart.

Different millers may have different opinions about the same wheat, and as indicated herein some sorts may have special values in different localities, but as a miller trading in the London district, I should put the ten in the following order having regard to all the points mentioned—

1. Pusa 6.
2. Lal Kasar Wala.
3. Punjab Type 9.
4. Gujar Khan.
5. Muzaffarnagar grown at Pusa.
6. Punjab Type 16.
7. ,, ,, 14.
8. Muzaffarnagar grown at Lyallpur.

9. Muzaffarnagar grown at Muzaffarnagar.
10. Australian 27.

I find great difficulty in answering your question as to the relative money values of these ten Indian wheats and Canadian and American grades. Canada and the U. S. A. grow some poor weak wheats, and I would certainly pay as high or even a higher price for any of the ten as I would for Canadian Winters, or for the wheats grown on the Pacific slope of the U. S. A., or for most of the U. S. A. winter wheat shipped as they are with all their uncertainties as to grading, but these Indians are quite different to Canadian or U. S. A. Spring wheats, and are not comparable with them. So long as the world grows so much more weak wheat than strong wheat, and so long as millers are compelled to supply flours of good or great strength, wheats capable of yielding flour from which tough, stable doughs and big loaves can be made will command a large premium.

Some authorities measure strength by the number of loaves a given quantity of flour will produce, but a reliable opinion cannot be formed on this point on small lots such as you sent me. It is, however, quite safe to say that the better of your ten would rank high on this point. The relative value of Indian wheats has already gone up a great deal as a result of improved cleaning and greater reliability in quality, and if wheats as good in intrinsic quality, as well grown, as clean and as dry as say the first six on my last list are shipped here from India, the growers can rely on a still further increase in their relative value in competition with the wheats of the world.

ALBERT E. HUMPHRIES.

It will be seen from this report that the four best wheats from a milling and baking point of view are hard wheats. Further, these varieties are also hardy wheats, good yielders and with good straw and in two cases at least with considerable resistance to rust. The soft wheats such as Muzaffarnagar white are, comparatively speaking, inferior wheats.

The extension of the cultivation of soft white wheats in India for export to Europe dates from the year 1883, when a report by Messrs. MacDougall Bros. of London, on the milling and baking tests of four parcels of Indian wheat was published.[1] These wheats were as follows :—

(1) Soft white from the Meerut and Muzaffarnagar districts.

(2) Soft red from the Meerut district.

(3) Hard red from the Banda district of Bundelkhand.

(4) Hard white from Khandesh in Bombay.

These wheats were milled in London by the then ordinary process of grinding under mill stones and also by the Hungarian or roller system which was at that time a novelty in Great Britain. Comparisons were made with English, American, Australian, Russian and Egyptian sorts both in the mill and subsequently in the bakehouse.

It is clear from the report that the hard red and hard white wheats were macaroni wheats and not bread wheats and are not usually exported to England for baking purposes. The soft white wheat from Muzaffarnagar was considered to be the best of the four, and, from that time, its cultivation and that of similar weak soft white sorts has been considerably advocated for export purposes. That this has been a great mistake will be clear when it is remembered that at the time these tests were made, most of the wheats used in England were ground under mill stones for which hard wheats and especially hard red wheats were not very suitable. Since that time, however, the modern roller mills have entirely replaced the old mill stones in England. In these mills the hard flinty strong wheats of Russia and North America can be handled with ease, and red wheats are almost as good as white sorts. The use of these flinty wheats in turn set up a new standard of flour strength and they were used almost entirely to mix with the weak soft wheats which make up the larger portion of the world's production. Strong

[1] This report is published in *The Wheat Production and Trade of India*, Calcutta, 1883.

wheats are at a premium in England. In the last 25 years, therefore, the conditions of the wheat trade in England have been revolutionised both as regards method and material. No corresponding change has been made in the wheats exported from India, only weak wheats are exported and therefore it is not surprising to find that there is a belief in England that India can only produce weak wheats. Thus Humphries and Biffen[1] in a recent paper state "the fact that India, Australia and California export wheats no stronger than our own makes it clear that abundance of sunshine does not necessarily result in the production of strong wheat." This is no doubt true of the soft Indian wheats now exported, but we do not think it is by any means true of all Indian wheats.

That strong wheats are grown in India seems to have been first discovered by Farrer[2] in 1899, who, in a letter to the Revenue Secretary to the Government of India, dated August 9th of that year, stated:—"On account of the high strength of the flour they produce, I take the liberty of recommending to you for extensive propagation the first two varieties of the three mentioned above, for I regard them as the best of all the Indian varieties which thus far have come under my notice. Your Indian varieties appear to vary greatly in the quality of flour strength."

Many enquiries in the villages in the Indo-Gangetic plain have elicited the information that for his own use the cultivator prefers hard wheats, often hard reds. These he considers to be greatly superior in food value to the soft wheats grown largely for export. The people fully understand the value of the chewing test and for their own consumption prefer those varieties which yield a sticky mass in the mouth after mastication. It will be seen from the letter from Messrs. Ralli Brothers (Appendix B) that if hard wheats were put on the market, there would be little difficulty in obtaining a premium for them.

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1 Humphries and Biffen, *Journal of Agricultural Science*, Vol. II, 1907.

2 Farrer in the Proceedings of the Government of India (Revenue and Agricultural Department, Nos. 1—4, October 1899). These wheats came from Etawah and Muzaffarnagar in the United Provinces. The Muzaffarnagar wheat was not Muzaffarnagar white, but a beardless variety.

It will be evident from the above that the demands of the local and export trade are the same and both prefer hard strong wheats. The growth of weak soft white sorts for export is therefore a mistake. When the English millers realise that India can produce much stronger wheats than those at present exported, the growth of weak soft wheats will be given up and the hardier, more easily cultivated flinty wheats will take their place.[1]

[1] Yielding power will naturally have to be taken into account as well as grain quality and hardiness. In recommending new wheats to the cultivators it will be necessary to select those which combine hardiness and high grain quality with good yielding power.

VI.

NATURAL CROSS-FERTILISATION IN INDIA.

In general, the flowers of all the species and varieties of wheat are self-fertilised, pollination taking place before the extrusion of the stamens. The details of the wheat flower are well illustrated by Hays,[1] while there are good detailed accounts of the opening of the glumes and of the extension of the anthers both by Fruwirth[2] and by Hays. Koernicke[3] observes that the stigmas themselves sometimes protrude their fine points, when the glumes open at the top for the liberation of the stamens, and remain in the open even after the closing of the glumes.

Instances of natural cross-fertilisation in the field are not common. Some observers even go to the length of stating that natural crossing does not take place. Thus De Vries[4] states "wheat, barley and oats are self-fertile and do not mix in the field through cross-pollination." Garton[5] from his experiments in England comes to a similar conclusion. He states :—

"The first step was to ascertain whether natural cross-fertilisation actually existed in the cereals. At the time it was an accepted doctrine that all agricultural plants were open to artificial cross-fertilisation, but there were no definite or reliable records to prove that such was the case. On the settling of this question depended the possibility of the work attempted. The method adopted was as follows :—

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1 Hays, *Bull.* 29, *U. S. Dept. of Agriculture, Div. of Veg. Phy. & Path.*, 1901.

2 Fruwirth, l. c., Bd. 4, 1907.

3 Koernicke. l. c.

4 De Vries, *Species and Varieties, their Origin by Mutation.* 2nd Ed., 1906, p. 98.

5 Garton, *Journal of the Farmers Club*, 1900, p. 47.

A suitable number of heads of wheat were selected in a field crop, and the immature anthers were carefully removed from about half a dozen florets on each head, the remaining florets being left intact. The ovules in the florets from which the anthers had been removed had thus every opportunity to become fertilised by pollen either from the surrounding florets left intact upon the same heads or by pollen from outside sources. Not one single embryo was developed in the florets thus treated. This was considered sufficient evidence to justify the belief that natural cross-fertilisation did not exist."

Biffen[1] who grew over 200 varieties of wheat at Cambridge in England, says they are autogamous with rare exceptions, and he states "I have never met with a case of natural cross-fertilisation."

Darwin in *Animals and Plants under Domestication* states: "With respect to the natural crossing of distinct varieties, the evidence is conflicting, but preponderates against its frequent occurrence."

These observations, it will be observed, refer to comparatively damp climates, and it is no doubt true that in England natural crossing in wheats is exceedingly rare. We have so far only found three cases in the records, the first of which is quoted in the *Journal of the Board of Agriculture* of November 1905:—"It is an extremely rare thing to find a single case of natural cross-fertilisation. The possibility of such an operation being caused by bees is so extremely remote that it can be said to have no existence. Because of its rarity it may be well to put on record that in the course of the Committee's work one case or perhaps two have been met with.[2] A farmer, Mr. R. Cook, of Box near Bath, planted in 1902 a field with a mixture of Square-head's Master and Essex rough chaff—two sorts of wheat which from the breeder's point of view possess marked differences. When the crop matured, he came across a plant with nine ears of particularly robust growth. He propagated their contents (560 grains) and has supplied the

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[1] Biffen, l. c.

[2] The Committee referred to is the Home-grown Wheat Committee in England who for some years past have been working to improve the milling qualities of English wheats.

Committee with an ear of the progeny which certainly seems to indicate that a natural cross did take place. Extremely rare though such cases of natural cross-fertilisation may be, it is not at all difficult to cross-breed wheat artificially.''

Two more cases of natural crossing in England in which Red Fife was the female parent have been observed at Chertsey in 1906.[1]

Although natural crosses are very rare in the damp climate of England, it by no means follows that such occurrences are equally rare in other wheat-growing countries. In drier and more sunny climates, such as that of the continent of Europe and some of the wheat-growing districts of North America, it is quite possible that natural crossing is much more common. A perusal of the literature shows that this supposition is amply confirmed. Thus in Jersey, LeCouteur[2] found that a red-felted wheat gave rise to felted red, smooth red, felted white, and smooth white plants. Another case of natural crossing was noticed by this observer in a Kentish felted wheat which gave rise to both smooth and felted progeny. Koernicke at Popplesdorf records several cases of natural crossing in *Die Arten und Varietäten des Getreides* published in 1885. Thus on page 31 he states :—'' It will be seen that wheat is arranged for self-fertilisation, but that cross-fertilisation is not impossible. That the latter occurs in the field was proved by me by undoubted crosses which I obtained in the garden and from which I grew some peculiar forms.'' On page 49, in describing the varieties of *T. compactum*, Host., Koernicke states that this group more than any other is disposed to cross in the field. Thus his varieties 25, *rufulum*, Kcke.; 26, *creticum* Mazzucato ; 29, *crassiceps* Kcke.; 30, *rubrum* Kcke.; 37, *sericeum*, Al.; 38, *albiceps* Kcke.; 39, *rubriceps* Kcke.; 40, *echinodes* Kcke. ; were obtained from natural crosses. Further, on page 62, when discussing the varieties of *T. durum* Desf., he states that one of the difficulties in

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1 Report of the Home-grown Wheat Committee for the cereal year 1907.

2 LeCouteur, *The Varieties, Properties and Classification of Wheat*, 2nd Ed., Jersey, 1872, p. 132.

dividing the varieties lies in the fact that in the south there are many more intermediate forms to be found than is the case with the German wheats. He considers this is probably due to the fact that in certain countries the sowings are extraordinarily mixed—wheats from Valencia gave on sowing a large number of varieties. In such cases Koernicke considered that it is easier for crosses to occur and the limits of the groups to be lost.

Fruwirth[1] brings together most of the recorded examples of natural crossing in wheat. The possibility of cross-fertilisation is supposed to have been proved for *T. sativum*, Vill., by an experiment of Rimpau in which 59 per cent. of castrated flowers freely growing in a wheat field set seed and by a similar experiment of von Liebenberg's in which 20 per cent. of flowers in the same manner set seed. As mentioned above, Garton in a similar experiment in England obtained no setting. Rimpau observed the occurrence of spontaneous bastards when different kinds were grown next to next. He cultivated 60 kinds of *T. vulgare* for 15 years and found 17 cases in which one could assume spontaneous crossing. Hansen at Lyngby and Nilsson at Svalöf are of opinion that in warm good weather forms cross with each other which are generally considered only to be self-fertilised, and that crossing between common wheats and spelts occurs under such circum stances. Fruwirth states that at Hohenheim he also noticed similar results and also crossing between forms of *T. sativum* and *spelta*.

In the United States, Carleton[2] considers that natural crossing sometimes occurs, and states "In a majority of the instances above described the circumstances too are such that one cannot escape the thought that the abnormal heads found in the fields were the results of natural crosses." In Canada, Saunders[3] has described a case of spontaneous crossing in the field between Red Fife (female) and Rio Grande (male).

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[1] Fruwirth, l. c.

[2] Carleton, *Bull.* 24, *U. S. Department of Agriculture, Div. of Veg. Phy. & Path.*. 1900

[3] Saunders, *Bull.* 57, *Canadian Dept. of Agr.*, Oct. 1907.

As it appeared probable that natural crossing occasionally takes place in warm countries, we have paid considerable attention to this point in India. In the pure culture plots at Pusa, many hundreds in number, during the last three years no cases of natural crossing have so far been discovered.

At Lyallpur, however, the results were quite different. Of the single-ear cultures, sown in 1906, four proved to be natural crosses. Three of these ears were collected on the Lyallpur Farm in May 1906, one was found in the collection of U. P. wheats from Saharanpur sent to us by Mr. H. M. Leake. We had no suspicion of any of these wheats being natural hybrids when they were sown, but considered they were rare types of wheat in cultivation.

In the plot of Safed Ghoni (a smooth white beardless wheat) at Lyallpur in 1906, two white felted, slightly bearded, red grained plants were noticed. These were sown from single ears in 1906, and in 1907 both gave rise to mixed offspring. The first, labelled P 145 A, gave rise to felted white chaff plants with red grains. Five plants were bearded, five were slightly bearded and two were beardless. In 1908 they split up still further.

P 145 A.

FELTED WHITE CHAFF, SLIGHTLY BEARDED.
(PARENT EAR) 1906.

5 felted white chaff bearded 1907.	5 felted white chaff slightly bearded 1907.	2 felted white chaff beardless 1907.

The other plant, P 146 A, also split up into bearded and beardless smooth and felted in 1907 and still further in 1908 :—

P 146 A.

WHITE CHAFF, FELTED, SLIGHTLY BEARDED, (PARENT EAR), 1906.

Smooth white chaff.			Felted white chaff.		
2 bearded 1907.	3 slightly bearded. 1907.	1 beardless. 1907.	5 bearded. 1907.	17 slightly bearded. 1907.	6 beardless. 1907.

The beardless ear obtained from Saharunpur in 1906 (U. P. 158) gave rise to bearded and beardless in 1907 and split up still further in 1908. As the seed from which this ear was raised was sent from Cawnpore to Saharunpur, the crossing must have taken place at Cawnpore.

- U. P. 158. Smooth white chaff beardless (parent ear) 1906.
  - 16 bearded smooth white chaff 1907.
  - 14 slightly bearded smooth white 1907.

The fourth case of a natural cross found at Lyallpur in 1906 was in the plots of *T. compactum.* In Type 5 one of the felted beardless ears gave rise in 1907 to red-felted plants differing very much in density.

- P5 Felted beardless 1906.
  - 5 red felted beardless lax ..
    - white chaff felted ...
      - lax
      - dense
    - red chaff felted ...
      - lax
      - dense
  - 5 red felted beardless dense ...
    - white chaff felted ...
      - lax
      - dense
    - red chaff felted ...
      - lax
      - dense
  - 1 red felted beardless very dense ... (compactum type) 1907.
    - all dense felted ...
      - red chaff
      - white chaff 1908.

In the harvest of 1907 at Lyallpur a slightly bearded smooth red chaff lax plant, not at all like a compactum, was observed in one of the dwarf wheat plots. This was sown separately in 1907, and in 1908 gave rise to 12 bearded and 11 beardless plants. They could also be divided up into lax and dense and into red and white chaff. In the present year (1908) in 42 of the 108 plots grown from the produce of single ears sown in 1906, we observed stray plants, often more than one in a plot. In many cases these were red or white chaff, felted, bearded, red grained plants, and most of them appear to be first generation of a cross between type 9 (Lal Kale Kasarwala) and the type in which they were found. These must have arisen either from natural crossing in 1907 or from stray seeds (either left in the soil from a previous crop or brought accidentally by ants, birds or in the irrigation water). As they are different in appearance from any known wheat at Lyallpur, and as natural crossing has already been proved by us to occur in the Punjab, we consider it exceedingly probable that these stray plants are natural crosses in the F_1 generation. Upwards of 100 of these supposed natural crosses will be sown this year and the results will be published in a subsequent paper. We are inclined to believe that in the Punjab in good years natural crossing is exceedingly frequent, especially when one of the kinds sown is type 9. In 1907 it was observed that the glumes of this sort open to a very wide extent when the anthers are ripe and liberate a vast amount of pollen into the air. As our plots were surrounded by a belt of this wheat on all sides, there were abundant opportunities for its pollen distribution. The season at flowering time was very dry and sunshine was abundant. Our artificial crosses made at this period at Lyallpur gave nearly 100 per cent. of fertilised grains. There is no doubt, therefore, that the season was a favourable one for natural crossing to take place. In conclusion, our opinion so far is that in the Punjab natural crossing is possible to such an extent that great care will have to be taken to keep the sorts pure and that plots grown next to each other must be very carefully rogued every year. At Pusa where, as a rule, the air is much damper at flowering time, natural crossing in the field seems to be very rare

APPENDIX A.

From A. E. Humphries, Esq., Weybridge, to the Imperial Economic Botanist, dated Weybridge, July 13th, 1908.

I duly received your letters of May 21st and 28th, and the 25 small samples of wheat have since come to hand. None of the ten large sample lots for milling and baking tests has yet arrived, but, in accordance with your request, I have examined the 25 small samples without waiting for the larger ones, and send you herewith my opinion as a British miller upon them.

When I speak of strength, I mean "a flour capacity for making big shapely loaves." Its capacity for making a large number of loaves from a given quantity of flour is in my view another matter upon which nobody can safely express an opinion by merely looking at samples. Of the many points upon which a miller bases his estimate of value in buying wheats, strength is the one to which pre-eminent importance is attached on almost all our United Kingdom markets. The very strong wheats of the world appear to be grown in countries where great heat is accompanied by a substantial or large summer rainfall, and as yet I have not come across any Indian wheat, which, on its own merits, in other words, when it is used for bread-making by itself, would come into our category of very strong wheat. I shall watch with very great interest any attempts you make to produce such wheats, especially if you experiment with Fife, but, in the meantime and particularly for my immediate purpose, I shall base my estimate of the commercial value of your wheats principally on their relative strength and the whiteness of the flour which they would yield under our modern conditions of milling. In this connection, I should like to point out that there is no invariable connection between the quality of the flour produced from the kernel of the wheat berry and the colour of the skin. A red skin does not necessarily indicate strength, nor does a white one necessarily indicate weakness, and sometimes the flour from red wheat is much whiter than the flour from white wheat. I have also to take into account how the wheats you have sent me would suit the methods of cleaning and milling in common use here. For instance, among your dwarf wheats are two (Nos. 7 & 4) which are extraordinarily small in the berry, so small that millers would hesitate to buy them if they contained any small seeds, because the machinery used for extracting the small seeds would take out

simultaneously a very large proportion of the wheat berries themselves. For that reason and having regard to the practical certainty of getting some small seeds into the bulks grown under commercial conditions, I would not recommend the growth of wheats 7 & 4, nor even of Nos. 5 & 6 unless there is some other characteristic, of which I know nothing, to strongly recommend them.

In recent years, a considerably increased quantity of Durum (Macaroni) wheats have been sold on British markets for ultimate use in bread-making, although as the alternative name implies their original or better use is for the manufacture of macaroni. Their great and inherent hardness is very different to the apparent hardness of your ordinary wheats, in which the hardness is due to mere absence of moisture, and in the estimation of millers making flour for bread-making purposes, Durum wheats are now, and are likely to be, at any rate for many years to come, worth much less money than your ordinary wheats. In all wheats, and especially in Durums, uniformity of texture is a most important desideratum. Millers in preparing their wheats for milling (the separation of husk from kernel) seek to get all wheats in their mixture into one uniform condition and with that object prepare some wheats very differently to others, before the blending of the various sorts is made. From this it would be obvious that growers or dealers in grain should, so far as possible, aim at exporting grain as uniform in texture as possible. This remark applies to your ordinary wheats as well, and affects my judgment on your samples. The principle of a remark I made concerning your dwarf wheats applies also to your Durums, but in another way. Our mills are fitted with elaborate systems of sifting machines in which the wheats pass through perforations in the sifting medium and large impurities pass over them. Of course, if millers found any additional commercial value for other reasons in very long berried wheats and could get a sufficiently large and regular supply, they would make the necessary changes in machinery, but such wheat as your No. 3 would pass over standard sieves into or with the large impurities, and in this case also, I would not recommend the export to the United Kingdom of such wheats for flour milling purposes, unless there be some strong recommendation, the existence of which I do not now suspect.

I note with much interest the cleanness of your samples, that is to say, their freedom from dirt, barley, seeds, and other extraneous matter. When I was President of the National Association of British and Irish Millers, I attended conferences of shippers, merchants and millers called to deal with the grave abuses which had been introduced into the Indian wheat trade, whereby, so we learned, such impurities were deliberately added to wheat with the object of obtaining for the sellers a greater monetary return. As a result of the arrangements arising out of those conferences, a great improvement has been brought about, but I would like to take this opportunity of remarking that if Indian wheats could be bought here regularly as clean and good as your samples, British millers would pay better prices than they do for them. Manitoban wheats fetch higher prices

on our markets than the corresponding grades of United States wheat because buyers believe they are more likely to get good deliveries of the former than of the latter, and Indian growers and dealers should realise that any action of theirs whereby confidence in the regularity of good deliveries is injured or destroyed, must in the long run do them much more harm than any temporary gain they may get.

Complying with your request to arrange the 25 samples in their order of merit, I set them out as follows :—

"Common wheats": Red:

9.
8.
22.
13.
14.
15.
23.

"Common" white wheats:

12.
10.
21.
17.
18.
20.
24.
19.
25.
16.
11.

In my opinion there is no difference in money value between those I have bracketed together. In case you would like me to put all the "Common wheats" in order of merit without making the distinction as to their colour, I set them out as follows :—

9 Red.
8 Red.
12 White.
10 White.
21 White.
17 White.
22 Red.
13 Red.
18 White.
20 White.
24 White.
19 White.
25 White.
16 White.
14 Red.
15 Red.
11 White.
23 Red.

Durums :—1, 3, 2. As we do not make macaroni in the United Kingdom, I think either of these would realise less money than any of the Common Wheats.

APPENDIX B.

From A. E. Anastasiades, Esq., Manager of Messrs. Ralli Brothers' Agency, Lyallpur, to the Imperial Economic Botanist, Pusa, dated Lyallpur, 12th May, 1906.

Wheat.—With reference to the conversation you had with the undersigned, our Karachi Principals write to us as follows :—

"The reason why we pay a better price for soft white wheat is that Great Britain and the North Continent, which take the bulk of Karachi wheat, generally prefer soft wheats.

"However, if purely hard wheat were produced in the Punjab in sufficiently large quantities to make it a merchantable description, and if the quality kept its characteristics from year to year and could be relied on to be matched at any time, an outlet for it could readily be found and possibly such wheat would command a premium.

"At present, purely hard wheat without an admixture of soft grain, reaches the Punjab markets in such small quantities that we are precluded from buying it on its own merits, and it has to be mixed in the so-called soft descriptions."

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MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE MULBERRY DISEASE CAUSED BY CORYNEUM MORI NOM. IN KASHMIR WITH NOTES ON OTHER MULBERRY DISEASES

BY

E. J. BUTLER, M.B., F.L.S

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The Twig Disease of Mulberry.

(*Coryneum Mori* Nomura.)

The disease caused by this parasite is probably of long standing in Kashmir. It definitely attracted notice for the first time in 1906, when there was a severe outbreak in the State mulberry nurseries, near Srinagar. Previously there is no record of losses in the mulberries from disease, but it is quite possible that earlier outbreaks would have escaped attention, and there is nothing to indicate that the disease is a new one. In the two years since 1906, the damage has been slight in the nurseries; probably the climatic conditions which favoured attack on the young trees have not since been repeated. Outside India the disease is only known in Japan, whence it was described for the first time, and the fungus named by Nomura* in 1904.

Nursery stock is not alone affected. It is fairly prevalent on full grown trees of all ages in different parts of the Valley, and must be responsible for a considerable reduction in the output of leaves.

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* Nomura, H. Intorno alla ruggine del Rengeso (Astragalus sinicus L.) e a due micromiceti patogeni del Gelso (Atti Istit. Bot. Univ. Pavia, n. ser, Vol. IX, 1904, pp. 13-14).

The parasite attacks the smaller branches, usually near the base. It is rare on those over an inch in diameter and is localized, extending only from one to three inches along the branch. At first it is usually confined to one side, but it always eventually affects the whole circumference of the attacked portion. Externally it is visible by the bursting out of a number of hard black cushions of fungus tissue, through angular cracks in the bark (Plate I, fig. 1). The whole of the affected area is slightly depressed and darker than healthy portions of the branch. The branch is killed above the attack, but internal spread backwards to healthy parts of the tree does not occur. The disease is thus truly local, attacking and killing individual branches only ; where the attacks are multiplied, the whole tree naturally suffers through insufficient nourishment. Some old trees were seen, much stunted, covered with dead branches, and bearing leaf only on feeble shoots arising directly from the trunk or older wood ; it is possible that these may be eventually killed, but no case where death resulted was seen. In the young nursery stock the attack may occur on the main stem near the ground level. In the outbreak of 1906, seedlings of the second and subsequent years were attacked and had to be cut back right to the ground in many cases. They then for the most part threw up healthy shoots from below. The young tree in the foreground of the photograph, reproduced in Plate I, fig. 2, was affected at the base of the leading shoot, just above a large pruned-off branch. This position near a cut branch or above a fork is very common and a possible explanation will be given below. Old trees are usually attacked in the young shoots of the current year's growth, which arise immediately below branches broken off during the silk-worm rearing season in April.

The fungus is not confined to living mulberry trees, but is also found on dead prunings and broken off branches on the ground. On these it may cover the whole of the branch, instead of a small part, as on living trees. It would thus appear to grow more freely within dead than within living tissues. Many parasites have this character, but are none the less destructive to living plants when they come into contact with them.

It has already been mentioned that the seat of attack is usually near the ground or above a fork in seedlings, and near the scars left in breaking off branches in older trees. The outbreak in 1906 followed a heavy fall of snow in the early spring ; this partly thawed and was succeeded by frost. The result was, as pointed out by Monsieur Peychaud, Director of Horticulture, Kashmir, that the seedlings were nipped near the ground and above the larger forks where snow had collected, and the bark was injured. The attacks in the older trees are always near a wound. The branch shown in Plate I, fig. 3, which is one of many such seen, shows a patch of infection around every scar left by removing the leaf-bearing side twigs during the plucking season. These facts all point unmistakably to the fungus being one of the large class known as "wound parasites" common in woody plants. Such parasites, as the name implies, attack their victims only through wounds, not through the unbroken surface of the plant. Anything which injures the surface—not only pieces broken or cut off but the holes made by insects and the bruises caused by hail or ice—may be sufficient to allow of penetration.

The wound parasitic fungi are found most commonly on dead wood. Ordinarily they are unable to grow through the cork which forms the protective bark of living trees. If this be cut away and the wood below exposed, many of them can then penetrate and exist by consuming the living tissues of the tree. Even in these cases, however, entry is much facilitated by the wound having been made in such a manner as to kill a portion of the wood as well as removing the bark. The fungus grows for a time on the dead wood around the wound, and having accumulated a store of nourishment, gains vigour enough to enable it to attack the living tissues beyond. Hence, while all wounds that are sufficiently deep may admit a parasite of this nature, wounds which are not clean-cut, but are jagged and leave splinters of dead wood attached to the tree, do so much more freely.

A careful search for *Coryneum Mori* on other plants led to its discovery on a rough-leaved jungle tree, *Celtis caucasica* (Kash. *Brimij*). It produces an exactly similar disease to that on

mulberry. The tree is not uncommon in the cultivated parts of the Valley, but is not likely to play much part in disseminating the disease.

DESCRIPTION OF THE PARASITE.

THE body of the parasite, as of fungi generally, is composed of numerous branching threads. These penetrate throughout the tissues of the attacked portion of the branch, where they are naturally hidden from view ; they can only be seen on examining microscopically very thin sections of the wood, such as that, a portion of which is shown in Plate II, fig. 2. The examination of such sections shows that every part of the branch-tissues becomes infected, pith, wood, bast and bark. Towards the centre of the branch the threads are mostly colourless, while nearer the surface they are deep brown. They vary greatly in size, from large thick-walled brown threads, such as those in the large vessel of the wood to the left in fig. 2, to fine colourless ones in the small cells of the inner part of the wood and in the pith. They grow from cell to cell with the greatest ease, boring through even the thick walls of the large vessels. Towards the surface of the wood they begin to accumulate into twisted, brown masses. These increase in the inner layers of the bark, and it may be noticed that whereas the walls of the wood-cells are not materially altered, those of the bast and inner bark are largely destroyed by the dense fungus growth. Immediately under the cork cells of the bark, numerous solid cushions of fungus tissue are formed by the continued branching and intertwining of masses of threads. These become divided by cross walls into rounded or angular cells, whose appearance in section under the microscope is shown in the central part of fig. 1, plate II. Along the margin of these cushions, spores are produced in large numbers as shown in the figure, and, by the continued growth of cushions and spores, the bark is ruptured. Hence each of the ruptured areas on the bark visible in the photograph in Plate I, fig. 1, is lined by a black cushion of the fungus similar to that shown in vertical section in the figure, from the surface of which quantities of spores are set free into the air. The mode of

formation of the spores is shown in fig. 3, and the different shapes assumed by them in fig. 4. *

The spores germinate readily in water, putting out colourless threads from several of the cells into which each spore is divided (fig. 5). These threads branch freely and become divided up into short lengths by cross walls. Infection of the wounds on mulberry branches no doubt takes place as the result of such spores (which are very minute, measuring only from 25 to 40 by from 10 to 18 thousands of a millimetre in diameter) being blown about from the branches of previously attacked trees or from prunings on the ground. The threads penetrate into the wood and there take the appearance shown in fig. 2. Fig. 4, plate IV, shows the microscopic appearance of the threads produced from spores germinated on dead mulberry wood in a moist still atmosphere ; under these conditions the fungus forms a fine white or grey mould-like growth on the surface of the wood. It will be noticed that the side branches show a tendency to fuse by their tips with other branches.

Treatment.—In considering the best methods of checking this disease, the two cardinal points to be borne in mind are that the parasite can be found on dead branches and twigs of the mulberry, whether prunings or broken off from any other cause, and that all its characters go to show that it is a wound parasite, attacking healthy trees only through unhealed scars left when branches are removed.

It is a fortunate circumstance that in Kashmir, as in most other parts of India, dead wood of any sort is not left long on the ground, but is promptly gathered for firewood. In the nurseries, however, this is not the case, and here care should be taken that the prunings and all broken twigs are regularly removed and burnt. Excepting for this matter the treatment of the trees in the

* The spores are often divided by vertical as well as by cross-walls, as the figures show. In the genus *Coryneum* the walls are usually transverse only. A few species are, however, already known that have occasional vertical walls (e. g., *Coryneum Notarisianum* Sacc. on oak and birch twigs), and it seems better to refer the mulberry fungus to this genus than to form a new one to receive it.

nurseries leaves nothing to be desired. The young trees are exceptionally strong, and the pruning is such as to secure well-shaped trees, capable of bearing the maximum quantity of leaf if properly treated afterwards. The superfluous wood is removed by clean cuts, which are rapidly healed by the formation of protective wound tissue. Except in the event of unavoidable injury such as that caused by frost in 1906, there appears to be no reason to anticipate a recurrence of the disease in a severe form in the nurseries.

The condition of the trees from which leaf is actually gathered in the silk-producing villages is very different to that of those in the nurseries. They are of all ages and sizes, up to very large old trees preserved, no doubt, by the rule prohibiting the felling of mulberry trees in the Valley. Contrary to what should be the case, the young trees are not, at least in those villages that I visited, giving as much leaf proportionately to their size as the old ones, and neither are giving nearly as much as they should under proper treatment. This is entirely due to the neglect of pruning and to the manner in which the leaf is gathered.

It would be impossible to exaggerate the damage which is caused at present by the clumsy and ruthless treatment of the bearing trees. I should say that it is quite out of the question for the industry to maintain its present extent, much less to increase, unless this matter is more carefully attended to and the care of the trees secured by instruction and stringent regulations.

The pruning of the mulberry tree is little, if at all, less essential than that of the tea bush, where it is considered by many to be the most important individual operation in the tea gardens during the whole season. The objects aimed at are in both cases the same :—to induce the plant to assume a convenient shape, to increase or keep at a high average the yield of leaf, to retain or improve the quality of the leaf, and finally, to maintain these conditions for the longest possible time. In the silk-producing parts of France and Italy pruning is a highly scientific process and is almost universal in one form or another. A full account of the different methods adopted may be found in the "Traité sur le Ver à Soie du Mûrier et sur le Mûrier" by Maillot and

Lambert, published by Masson & Cie., Paris, in 1906. Even where regular pruning is not practised, care is taken to remove all dead wood, withered twigs and such as are useless for good leaf-production.

While there can be no question of the value of pruning, it is necessary to point out that bad pruning is often worse than none at all. The best results will be obtained if the plants are regularly pruned on a definite system from the nursery onwards. This could be quite easily secured in the young trees which have been distributed from the State nurseries, by periodical inspections. The treatment of the older trees is more difficult as they have been allowed to get into a condition from which it would usually be hopeless to expect to secure well-shaped trees. The most that can be done is to attempt to restore their vigour by judicious removal of all weakly shoots and of the less productive wood. What can be done in bad cases is shown in the photographs reproduced in Plate III, which were taken in the nursery under M. Peychaud's charge at Harwan. But the greatest care should be taken to secure clean-cut wounds, and where the axe is used at all, it should be followed by trimming with a sharp knife. The methods followed at Harwan may be taken as a safe guide.

As already mentioned, *Coryneum Mori* can grow on dead mulberry wood on the ground. It is not less common on dead twigs found on the trees, and every such twig left may serve to increase the production of spores and the consequent danger of infection to healthy parts.

The systematic pruning of the trees is called for not only on account of the necessity of removing all dead and weakly twigs and useless wood in view of the manner in which the injurious action of the twig fungus is favoured by their presence, but also because of the improvement in the quality and amount of leaf which it causes. The two photographs reproduced in Plate III show the result of pruning. They were taken from trees of the same variety growing near together and about the same age. The pruned tree is thickly covered with strong leaf-bearing shoots and the leaves are large. It was entirely free from disease. In the

unpruned trees a number of the branches (of which some are visible on the extreme left) have been killed by *Coryneum Mori*; the remainder are scantily furnished with small, ill-nourished leaves. Though the branch system is larger, the total leaf is much less. It is well known that the quality of the leaf has a marked effect on the health of the worms and on the amount and quality of the silk produced. There can be no doubt from a comparison of the photographs that the pruned tree is superior in quality of leaf as in every other respect to the unpruned.

In Europe it is usual to gather the leaves only, whereas in Kashmir branches are taken; it is apparently contended by some that this, in large trees, serves the purpose of pruning. This would probably be the case to a certain extent if the branches were cut with any system and if the cutting were done with reasonable care. As it is, the trees are being directly injured instead of improved in power of leaf-production and in quality of leaf, by the hacking to which they are subjected. Branches thicker than a man's finger are not supposed to be taken, but little attention is paid to this regulation, and it is probably not a useful one if applied indiscriminately. On young trees it does not prevent over-plucking; on old, it leaves much of the useless wood behind. Trees can be seen in most villages in which so much young wood has been removed that the leaf-bearing twigs of the current year's growth spring largely from the trunk or main branches. Such shoots are usually of short growth, bear often small leaves, and never form the basis for a new system of leaf-bearing shoots in the following year. In many comparatively young trees seen, the leaf-bearing shoots were for the most part dead at the tips and for a variable distance back from the tips. This condition, which is known as "dying back," is a common result of defoliation of plants from any cause, such as the attacks of insects or fungi or from frost. Excessive plucking of leaves in tea and mulberry is known to lead to dying back, and an examination of the trees left no doubt that this was the cause here. The very rapid growth of the industry in the last few years is responsible for this state of affairs. The smaller trees, being easily reached, are

stripped of the greater part of their young leaf-bearing wood during the rearing season. The sudden loss of a large proportion of leaf so affects the upward current of water and food material from the soil that the younger tissues of the twigs dry up and die of inanition.

This over-plucking affects chiefly the younger trees, as the older are not so easily denuded. Trees of all ages are, however, injuriously affected by the manner in which the branches are gathered. If the cutting were done with a proper implement so as to secure a clean-cut surface on the part attached to the tree, the wounds would be rapidly occluded and strong young shoots would be thrown out below the point cut. As a matter of fact, clean cuts are the exception rather than the rule, and much of the crop is apparently obtained by the simple method of breaking the twig in the hand, leaving naturally jagged splinters and wounds behind. The parts immediately around and below these wounds rot and die as with any other tree, and the buds just below the portion removed, whence the next season's leaf should come, are often killed outright or injured. Numbers of twigs of the current year's growth may be seen springing from the margins of old ragged wounds, and these bear, as might be expected, small feeble leaves and show a tendency to die back from the tip.

Unoccluded, jagged wounds with dead splinters attached, of just the sort that will most readily allow of infection by a wound parasite, the presence of the latter on dead twigs attached to the trees, numbers of weakly shoots arising from the injured branches, these are the conditions which are common in the mulberries of the silk-worm rearing villages, and which constitute a real danger to the industry. That under favourable conditions the twig fungus is capable of causing great damage, is evident from the experience in the nurseries in 1906. The two years that have intervened may be taken to be years when conditions were against the parasite ; the nurseries have practically escaped, though the losses in the villages are appreciable. Heavy injury to older trees was not reported in 1906, but would not be so likely to attract notice as in the nurseries ; there is no reason to believe, however, that the former

are less liable to injury from this cause than the latter. The reverse is likely to be the case. The great increase in the demand for food for the worms in the past few years has greatly improved the prospects of the parasite finding wounds through which it may gain an entry into the trees. Hence there is a decided possibility that the disease is on the increase, and it would seem advisable to attempt to diminish the annual moderate loss and the risk of periodical heavy losses.

The first requirement is an improvement in the manner of obtaining the crop. As already mentioned, branches, not individual leaves, are gathered. I could not discover any real reason why this is done except that the worms are fed on the floors of the houses instead of on frames, and the presence of branches ensures a certain amount of ventilation from below and enables the worms to mount when about to form cocoons. From the point of view of diminishing risk of infection by *Coryneum Mori* leaf-plucking would be preferable. Frames would not be expensive and the capacity of the rooms would be increased. The relative advantages of the two systems under the conditions prevailing in Kashmir might be more fully inquired into and the change gradually introduced if found suitable.

A good cheap knife for cutting the branches is much needed. Several patterns of pruning implements are used in France and Italy, each with its own advantages. Some are described and figured in Maillot and Lambert's book referred to above. There would be no difficulty in making the simpler forms in Srinagar, probably very cheaply. The cutting implements used in Kashmir in gathering the branches are primitive to a degree and incapable of producing a clean cut.

Every opportunity should be taken of instructing the silk-worm rearers regarding the necessity of removing the branches in as clean a manner as possible, and of trimming the wound where necessary so as to avoid leaving splinters attached to the tree. Clean wounds will heal naturally and rapidly and the danger of infection will be reduced. At the same time the injurious results of over-plucking should be explained.

During the pruning operations special attention should be paid to removing all dead twigs and unproductive or feeble wood. This is a point which is liable to be overlooked, but its importance is great, not alone directly because of the danger from twig disease, but also because such wood is merely a drain on the tree and diminishes the quality of the leaf. The prunings should, of course, be burnt, but this will probably not require any special precautions being taken as they will be removed for fuel as soon as permission is given. In the nurseries this point requires to be attended to.

Once pruning is adopted as a regular practice and the methods of gathering the crop are improved in the manner indicated above, I feel confident that all real danger to the industry from an increase in this disease will disappear.

Mulberry Leaf-spot.

(*Septoglœum Mori* (Lév.) Briosi & Cavara.)

This disease is extremely common in Europe where it is sometimes called mulberry leaf-rust though caused by a fungus not belonging to the true rusts. It occurs throughout Kashmir, but does not appear to cause much damage except in the moister parts.

It affects chiefly the younger leaves, which become covered with angular spots, pale brown in the centre and surrounded by a dark reddish-brown band (Plate IV, fig. 1). On the upper surface of these spots, and sometimes also on the lower, little raised pustules appear. In moist weather these swell up into rounded blisters of a pale colour from the development of numerous colourless spores. Affected leaves drop off prematurely and are avoided by the worms. In bad cases the reduction in leaf is said to amount to ten per cent. in individual trees, but this is only likely to occur in seasons of exceptional moisture, and even then is not likely to be general.

The spots are caused by a fungus whose filaments penetrate the tissues of the leaf but are limited in growth and affect an area usually not exceeding a quarter of an inch in diameter. After sufficient food has been accumulated from the living cells of the leaf (which are killed and turn brown) the parasite comes to the

surface to form spores. Cushions of dark fungus hyphæ are formed beneath the leaf epidermis, where they are early visible as small raised black dots. On the surface of these the spores appear and burst through the epidermis to be shed into the air (fig. 2, plate IV). The spores (fig. 3) are elongated, colourless, rounded at the ends, divided into segments by three to five cross-walls, and usually curved. They germinate readily in water and new spots are caused by the penetration of threads from germinating spores into the tissues of the leaf.

Treatment would not repay expenses in ordinary mild cases. In the nurseries it might become necessary in the event of a bad attack, when spraying with Bordeaux mixture would probably be effective. Pulling off and burning spotted leaves early in the season would much reduce the spore formation and consequently the spread of the disease from leaf to leaf.

Mulberry Mildew.

Phyllactinia Corylea (Pers.) Karst.

The mulberry mildew is fairly common in India and occurs also in Japan and Madagascar, but not, it would seem, in Europe. It has hence not been the subject of detailed researches, especially in the direction of treatment, as have the allied vine mildew and other common European mildews. Fortunately the disease does not appear to be ordinarily a serious one in Kashmir. In Madagascar it is said to attack, above all, mulberry trees planted near paddy fields or exposed to winds that have blown across marshy land. The losses are heavy in these cases, and would, no doubt, be equally heavy in India under similar conditions.

The fungus attacks only the leaves. These are covered with a fine white powdery layer over the whole or a part of the under-surface, and are sometimes deformed or stunted, especially if attacked when young. They are not liked by the worms and eventually turn brown and dry up. The parasite differs from the leaf-spot fungus in developing chiefly on the surface of the leaf and only sends short sucker-branches into the air-pores and the air-cavities

lying below (fig. 5, plate IV). From these, fine suckers penetrate into the leaf cells and kill their contents which are absorbed as food Instead of being limited in growth as in *Septoglœum Mori*, the threads ramify over the leaf surface for considerable distances and may eventually cover the greater part with their web.

Mulberry Mildew.

From the superficial web short branches stand up vertically into the air. On the top of each of these a single large spore is formed (fig. 5). The spread of the fungus from leaf to leaf is due to these spores breaking off from their stalks and being blown on to

the under surfaces of healthy leaves where they germinate and give rise to a fungus web which sends sucker-branches into the leaf.

A second spore-form is known but has only been found on a small number of leaves. It is produced in little hard reddish black receptacles visible to the naked eye as small, round, shining grains lying on the surface of the old webs (fig. 6). Inside each is a number of thin-walled sacks within which two or three spores are ultimately developed. It is probable that the latter ripen slowly, as mature spores were not found in any of those examined. This spore-form is concerned with the transmission of the fungus from season to season and through periods when food in the shape of living leaves is not available.

Though, as already said, treatment has not been tried, experience with allied diseases enables one to say with fair confidence that sulphur dusting, as practised in the vineyards against vine mildew (*Oidium*), is likely to prove successful. Or the leaves may be sprayed with potassium sulphide (liver of sulphur) solution, made by dissolving half an ounce of the sulphide in a pint of hot water and making up to one gallon with cold water. This is not likely to be required except in the nurseries, and from what I saw in 1908, is not at present required there.

The mildew is more destructive to young plants than to full-grown trees. Its attacks are likely to be worst in low-lying places and like most mildews damp hanging ground-fogs greatly favour its spread. Hence, in opening new nurseries, the site should be selected so as to avoid these conditions as far as possible. Similarly in planting out the nursery trees in the villages, high ground should be selected in preference to low, particularly in the lower parts of the valley, adjoining the Wular and Dal Lakes.

MULBERRY TRUNK-ROT.

Polyporus hispidus (Bull.) Fr.

THIS fungus belongs to the class of the large bracket-fungi which are familiar objects on the trunks of trees and on old logs. It is extremely common on mulberries and was found also attacking

apple, plum and apricot trees in Kashmir. In Europe it is known on these as well as on several other broad-leaved trees.

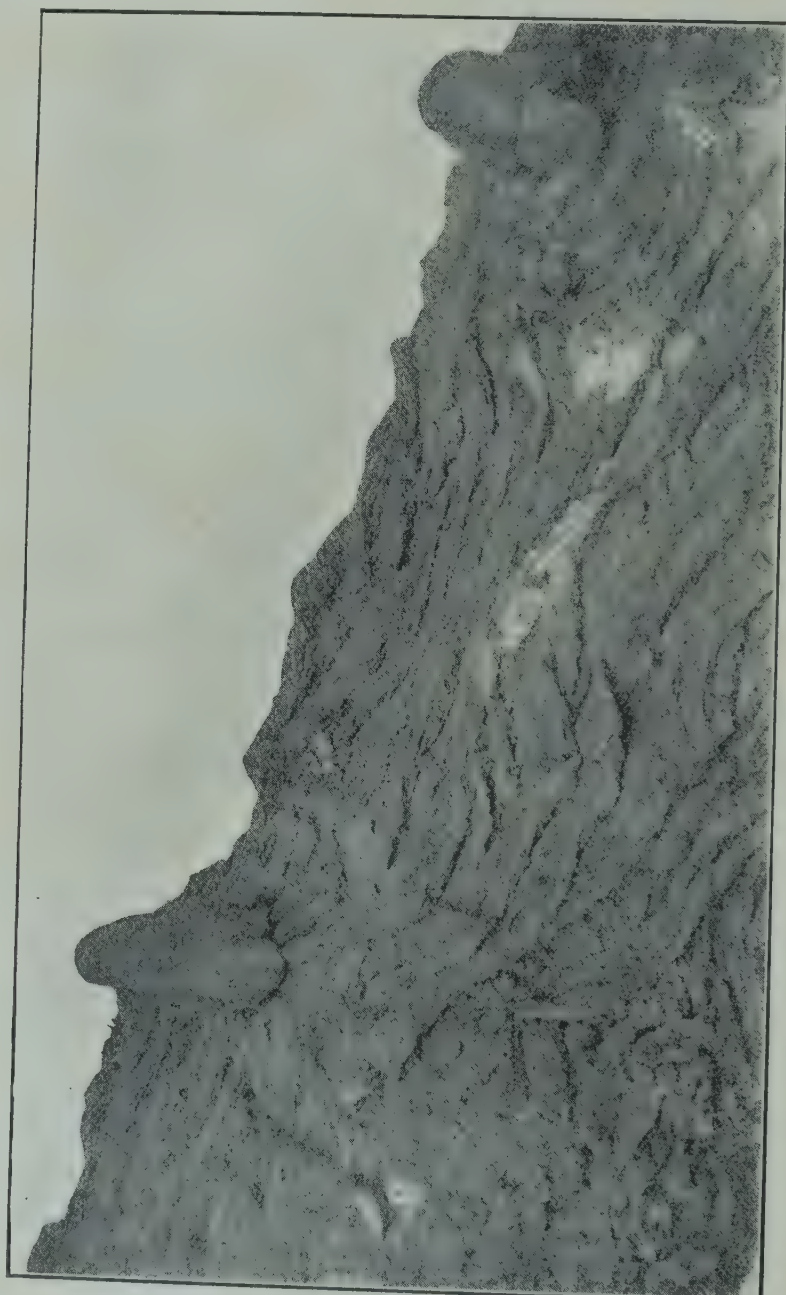
It is found usually on the trunk but also attacks the larger branches. Being a "wound parasite" the infection takes place by means of spores lodging on the scars which are so common on Kashmir mulberries owing to the manner in which the leaf is obtained for silk-worm food. In the scars left by removing large branches a portion of the heart-wood is exposed, and it is here that infection occurs. Scars left by breaking off small twigs which have no heart-wood, are not liable to attack, though, as already mentioned, they are the usual place of entry for the twig-disease fungus.

When the spores germinate, the young threads penetrate into the branch heart-wood and from that to the heart-wood of the trunk, attacking first the central portion and then the outer, younger layers. The tissues are little by little destroyed from within out, becoming soft, spongy and yellowish white. Separating the outer healthy layers of young wood from the rotten central portion, is a hard brown zone, consisting of cells filled with a brown, gummy matter; in this the parasite takes its main development. It is nourished in the brown zone mainly by the cell-contents while the walls are at first left unaltered. Only at a later period, when the cell contents are exhausted, is the wall corroded and the wood itself softened.

Branches attacked by this heart-rot dry up and die. The trunk may be almost completely hollowed, but often a ring of still living wood is left, which is sufficient to keep the crown green. In most cases it is probable that rotted trees are blown down before the parasite can directly cause their death, for while partially rotted and hollow trees are fairly common, few that are obviously near death can be found.

The fungus is perennial within the tree, and about August each year grows out to the surface to form spore-bearing organs. These appear externally on the trunk or main branches, and can be artificially induced to form, by exposing the heart-wood of a part where the threads are numerous, and keeping the wound moist.

The young spore-bearing body is a rounded knob of pale yellow colour, about an inch in diameter, extremely soft and containing a large proportion of water. It is formed of a great number of threads which grow together into a definite shape, forming a smooth mass in which all trace of the component threads is lost, though they are, of course, easily visible under the microscope. The mass now grows into a large, often almost



POLYPORUS HISPIDUS ON THE TRUNK OF A MULBERRY TREE.

hemispherical body attached to the trunk by a broad base and sometimes measuring as much as six inches across The upper

surface becomes strongly convex, the lower less or almost flat. Soon the colour deepens into a characteristic chestnut shade on the top, while the upper surface becomes clothed with thick soft hairs formed of agglutinated threads. At the same time hundreds of small pores are formed on the under surface, and these develop into long yellowish brown tubes, which often exude water in drops while forming, even in dry weather. The body remains soft until quite old when it becomes hard, black, shrunken and cracked. The inner flesh always retains a deep yellowish or almost chestnut brown.

Within the tube, spores are formed in large numbers on special cells which line their walls. Each such cell bears four spores on short stalks. The spores are smooth, single-celled, egg-shaped and brown. They are shed through the tubes into the air. Infection only takes place by means of spores blown from the spore-bodies on the surface of diseased trees.

The remedy consists in cutting out the affected part, when this is a branch, and can be recognised by the presence of the spore-bearing bodies ; in taking care to remove and destroy the latter as soon as they are noticed on the surface ; above all, in endeavouring to reduce chances of infection by removing the branches during pruning or when feeding the worms, in such a manner as to promote rapid healing of the scars. It is noticeable that the fungus is much commoner on mulberries than on apples or plums, and this is undoubtedly due to the abundance of unhealed wounds on the former.

It is probable that the regulation prohibiting the felling of mulberry trees in the Valley is too strictly enforced. There are many old trees hollowed by the action of trunk-rot, which would be better out of the way. They yield leaf of poor quality and bear annual crops of *Polyporus hispidus* which must lead to the infection of neighbouring trees. It would be a comparatively simple matter for the mulberry inspectors to mark such trees, whose removal could then be permitted on condition that they are replaced by a certain number of seedlings.

DESCRIPTION OF THE PLATES.

Plate I.

Fig. 1. Base of leading shoot of young tree of *Morus alba*, showing external characters of attack by *Coryneum Mori*. From a photograph.

,, 2. State mulberry nursery, Harwan, Kashmir, with young tree attacked by *Coryneum Mori* in foreground. From a photograph.

,, 3. Branch from a bearing mulberry tree, showing a patch of twig-disease at each scar left by removing side twigs.

Plate II.

,, 1. Vertical section through a cushion of *Coryneum Mori* in the bark of *Morus alba*. Magnified 125.

,, 2. Portion of a transverse section through the wood of a twig of *Morus alba* attacked by *Coryneum Mori*, showing the fungus threads in the cells and vessels of the wood. Magnified 500.

,, 3. Cells at the surface of a cushion of *Coryneum Mori* bearing spores. Magnified 500.

,, 4. Spores of *Coryneum Mori*. Magnified 500.

,, 5. Germination of the spores of *Coryneum Mori* when sown in water.

Plate III.

,, 1. Pruned tree of *Morus alba* at Harwan. From a photograph.

,, 2. Unpruned trees of same variety and growing near by. Many of the terminal twigs, especially of the tree to the left, have been killed by *Coryneum Mori*. From a photograph.

Plate IV.

,, 1. Mulberry leaf-spot (*Septoglœum Mori*) on leaf of *Morus alba*. Natural size.

,, 2. Section through a pustule of *Septoglœum Mori* on mulberry leaf. Magnified 333.

,, 3. Spores of *Septoglœum Mori*. Magnified 666.

,, 4. Portion of the aerial growth resulting from the germination of spores of *Coryneum Mori* on the surface of a block of mulberry wood.

,, 5. Section through a mulberry leaf attacked by mildew (*Phyllactinia Corylea*) showing external web sucker-branches penetrating the air-pores, and spore-bearing branches projecting downwards into the air. Magnified 333.

,, 6. Durable spore-receptacle of mulberry mildew. Magnified 70.

PLATE I.

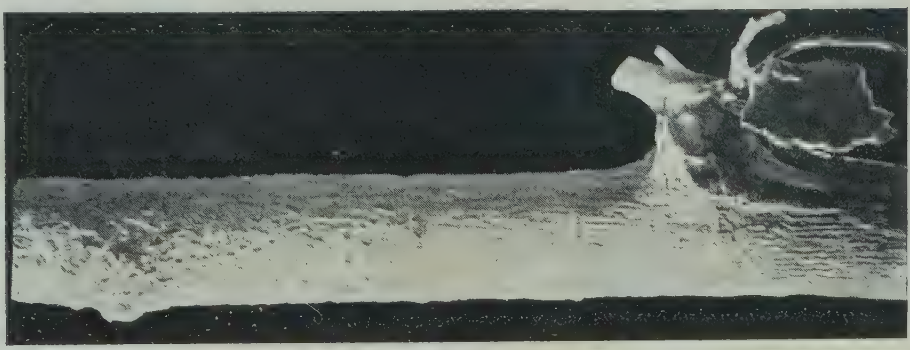


Fig. 1.

Fig. 2.
Coryneum Mori on Morus Alba

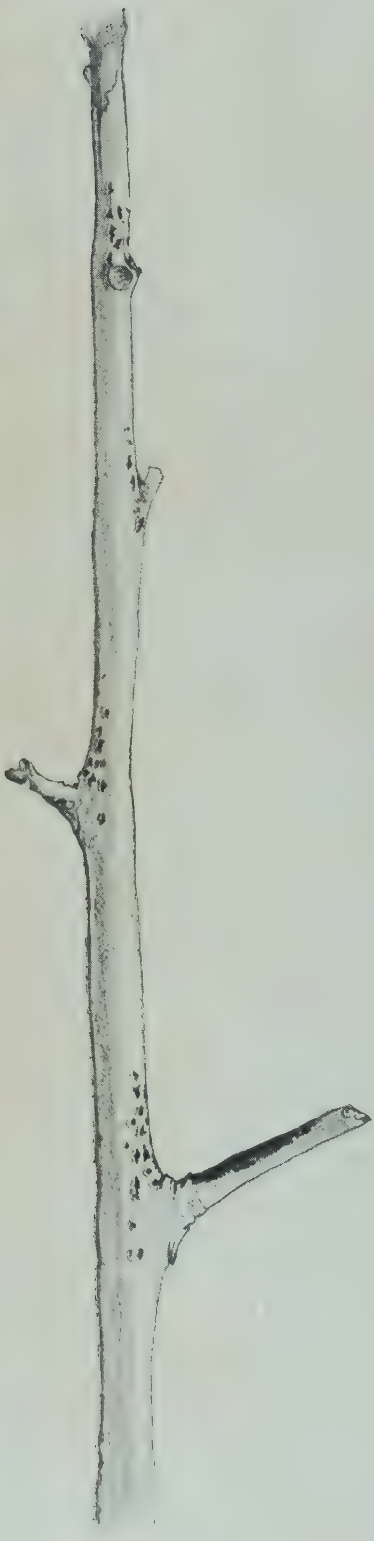


Fig. 3.

PLATE II.

Coryneum Mori Nomura.

PLATE III.

Fig. 1. Pruned.

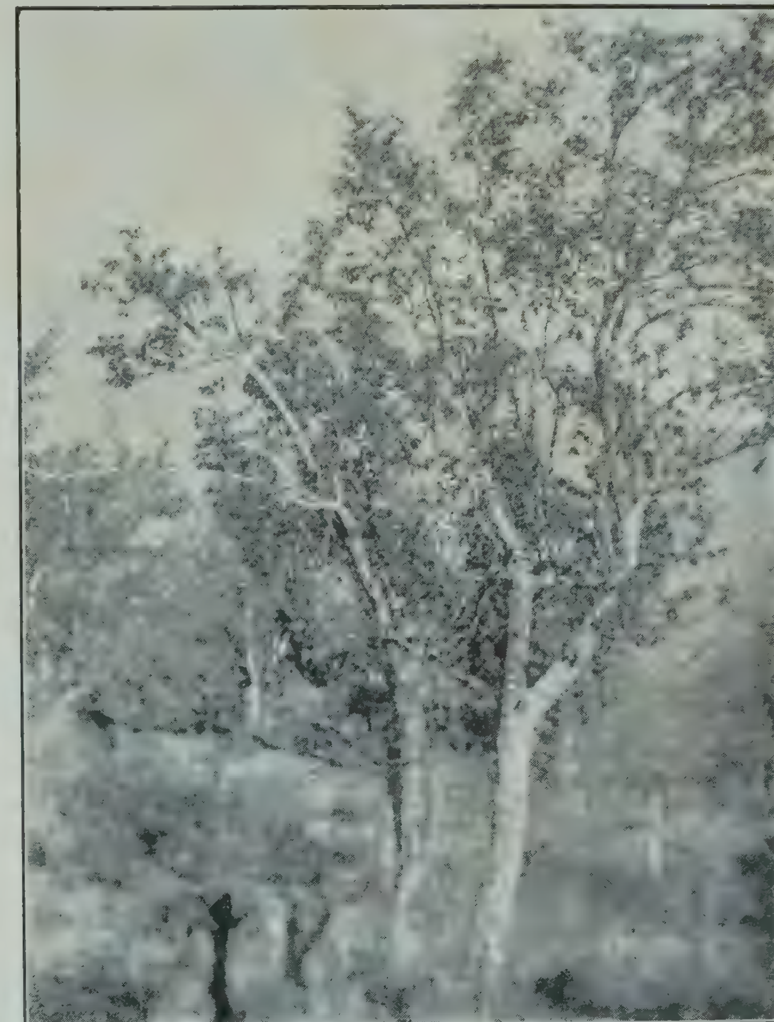
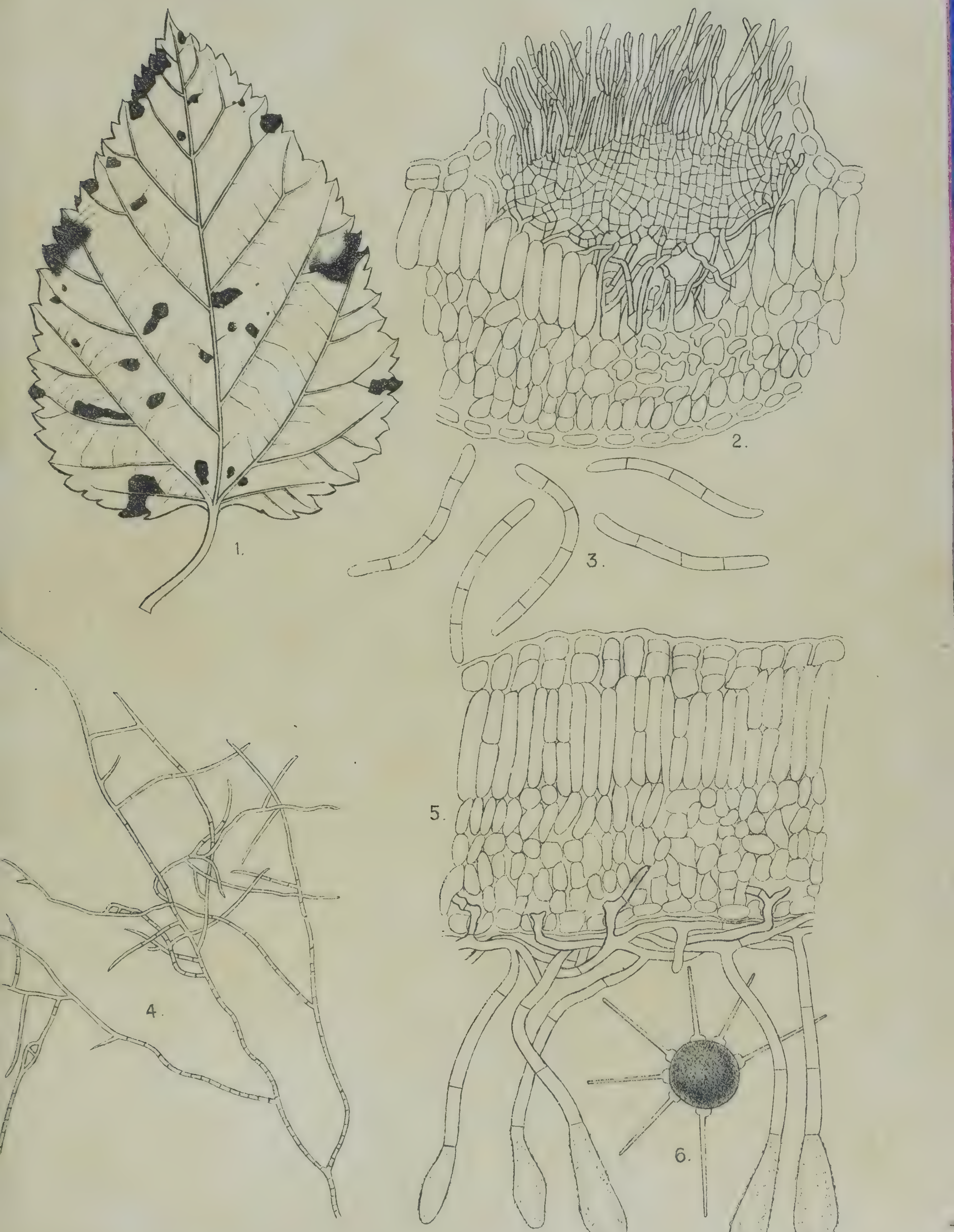


Fig. 2. Unpruned.

Effect of Pruning Mulberry Trees.

PLATE IV.



Septogloeum Mori (Lév.) Briosi & Cavara (figs. 1-3) Coryneum Mori Nomura. (fig. 4.) and Phyllactinia Corylea (Pers.) Karst. (figs. 5-6.)